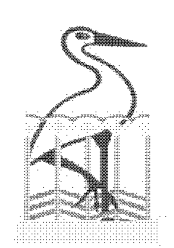


رئاسة مجلس الوزراء
جهاز شئون البيئة
الإدارة المركزية لحماية الطبيعة

بحيرة ناصر

مرجع عام

حلمى ميخائيل بشاى
سمير عشم عبد الملك
مجدى توفيق خليل

بحـــيرة ناصـــر

مـــرجـــع عـــام

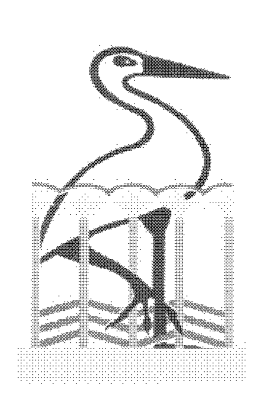
دكتور حلمى ميخائيل بشـاى
كلية العلوم – جامعة القاهرة

دكتور سمير عشم عبد الملك
المعهد القومى لعلوم البحار والمصايد

دكتور مجدى توفيق خليل
كلية العلوم – جامعة عين شمس

مطبوعات وحدة التنوع البيولوجى – العدد 11 - 2000

ARAB REPUBLIC OF EGYPT
CABINET OF MINISTERS
EGYPTIAN ENVIRONMENTAL AFFAIRS AGENCY (EEAA)
DEPARTMENT OF NATURE PROTECTION



LAKE NASSER

A TREATISE

Helmy M. Bishai

Samir A. Abdel-Malek

Magdy T. Khalil

Publication of National Biodiversity Unit. No. 11. 2000

بحيرة ناصر

تعتبر بحيرة السد العالي من المشروعات العملاقة خلال القرن العشرين ، كما أن السد العالي من الإنجازات الهندسية الضخمة ، قد صمد على مر السنين للفيضانات العالية وللزلازل . وقد أثبتت الأيام أهميته الحيوية لمصر ، فرغماً من المعارضة التى وبل بها من البعض – عند بدء إنشائه ، فانه بلاشك حمى مصر من فترة الجفاف التى تعرضت لها أفريقيا (983 –988) والتي وصل خلالها منسوب المياه في البحيرة إلى أدناه منذ إنشائه . ففي الوقت الذى كانت تشكو فيه البلاد الأفريقية من الجفاف وندرة الماء ، وفرت بحيرة ناصر لمصر احتياجاتها من المياه رغما من الزيادة المضطردة في عدد السكان ، وزيادة الرقعة الزراعية . كما أن السد العالي قد حمي مصر من الفيضانات العالية وعلى وجه الخصوص في السنوات الأخيرة (1998 ،999) حيث وصل منسوب المياه في البحيرة إلى أقصاه في نوفمبر 999 (181.6 مترا فوق سطح البحر) منذ تكوين بحيرة ناصر .

وكأى مشروع عملاق ، أثر إنشاء السد العالي وما تبعه من تكوين اضخم بحيرة صناعية في أفريقيا ، على النظام البيئي النهري وحوله إلى نظام بحيري حيث يغدو تيار الماء بطيئا والمياه شبه ساكنة ، وما يتبعها من تغيرات جذرية في نوعية المياه ، وفي تنوع البيولوجي للأحياء وطبيعة المنطقة ، وترسيب الغرين في البحيرة بدلا من حمله مع مياه الفيضان لزيادة خصوبة الأرض . لذلك توقع القائمون على تنفيذ المشروع وجود إيجابيات وسلبيات ، كان عليهم أن يتلافوا بقدر الإمكان تلك السلبيات ومعالجتها . منذ بدء إنشاء السد العالي ، بناء على دراسات وخبرة العلماء . ولا غرو فإنشاء السد العالي كان ضرورة حتمية لمصر في ظل الزيادة السكانية المستمرة ، والحاجة إلى التوسع الزراعي ، لذلك ففوائد السد العالي لا تقارن بالسلبيات التى حدثت والتى – من خلال الأسلوب العلمى – يمكن التقليل من آثارها .

ولعل من أهم مشروعات نهاية القرن العشرين التى انبثقت من بحيرة السد العالي هو مشروع توشكى " الذى بدأ العمل فيه منذ عام 996 . فقد انشىء مفيض توشكى جنوب البحيرة لاستقبال مياه الفيضان الزائدة خلال الفيضانات العالية أعلى من 178 متراً فوق سطح البحر) لتصريفه إلى منخفض توشكى . ومما لا شك فيه أن هذا المشروع سيسهم في تنمية جنوب الوادي ، بزيادة الرقعة الزراعية إضافة إلى توزيع العمران المصري ، بدلا من اقتصاره على ضفاف النيل الضيق .

لقد انتهى إنشاء السد العالى في مايو 1964 ونتج عنه تكوين إحدى اضخم البحيرات الصناعية في أفريقيا – بحيرة السد العالي التى تمتد لمسافة 496 كيلو متر ، منها 292 كم في الحدود المصرية و تشمل بحيرة ناصر ، و204 كيلو مترات داخل الحدود السودانية وتشمل بحيرة النوبة . وعند منسوب 180، 160 مترا فوق سطح البحر تبلغ مساحة بحيرة السد العالى 5815، 2370 كم2 ، ومتوسط عمق 21.5 ، 5.2م بحد اقصى 110 – 30 م ومتوسط عرض 8.9 ، 8 كم ويمكن الرجوع إلى ملخص للمعلومات الخاصة بالبحيرة في الجزء الخاص **بحيرة ناصر : حقائق وأرقام**" في نهاية الموسوعة الحالية .

وعند الإشارة إلى الدراسات التي تمت على بحيرة ناصر ، لا يفوتنا أن نذكر الدراسات التى قام بها مركز التخطيط الإقليمي لتنمية بحيرة ناصر بأسوان ، ومنها مجموعة البحوث والدراسات الرائدة التى قام بها المرحوم الأستاذ الدكتور أبو الفتوح عبد اللطيف مدير المشروع الإقليمي لبحيرة ناصر ورئيس أكاديمية البحث العلمى والتكنولوجيا الأسبق – ومدرسته العلمية و تى شملت دراساته وبحوثه معلومات أساسية خاصة في السنوات المبكرة لتكوين البحير ، ومنها الدراسات الطبيعية والكيميائية والبيولوجية ، وأسماك البحيرة ومصائده ، مما تعتبر مرجعا هاما للتعرف على مدى التغيرات التى طرأت على البحيرة منذ تكوينه ، كما أن الدراسات المتنوعة التى قام بها . بيلا انتز Béla A.G. Entz المدير الإقليمي لمشروع تنمية بحيرة ناصر من قبل منظمات SF/FAO/UNDP تعتبر من الدراسات الرائدة أيض . والجدير بالذكر أنه في عام 1981 تأسس مركز البحوث السمكي " التابع لهيئة تنمية بحيرة ناصر بأسوان ، بالتعاون مع كا ة دراسات المصائد بطوكيو ، اليابان ". ومن خلال أنشطة هذا المركز أمكن إجراء دراسات مستفيضة عن مصادر المصايد ، بيئة البحير ، والاستزراع المائى ، وتم إصدار ستة أعداد تحت عنوان : تقرير مركز البحوث السمكي ، والتى تضمنت نتائجها الموسوعة الحالية إضافة إلى نشر الكثير من البحوث فيما يختص ببحيرة ناصر بالمجلات العلمية اليابانية ، بالتعاون مع علماء المصايد اليابانيين . ولا يفوتنا ذكر الدراسة المتكاملة عن بحيرة ناصر التى قام بها العلماء اليابانيون والتى تضمنها التقرير النه ي في عام 1980 عن خطة التنمية الاقليمية المتكاملة منطقة بحيرة السد الع ي ي مصر " مع وكاله اليابان للتعاون الدولي (JTCA . وقد تضمن هذا التقرير المفصل دراسات عن التنمية المستقبلية للأنشطة المختلفة بمنط ة البحير ، ولكن لم يتم متابعة ما جاء بهذا التقرير ، بطريقة جادة للتعرف عما تم إنجازه والاستفادة من الدراس ت التي تضمنه .

وتشمل الدراسات السابقة عن البحيرة بحوثا منشورة وتقارير دورية ونـدوات ومؤتمرات ورسائل علمية وغيره ، إلا أن معظم هذه الدراسات محدودة التوزيع وغير متاحه للدارسين والباحثين وصانعي القرار للتعرف على التطور في البحيرة منذ تكوينه ، وما يمكن أن يحدث فيها مستقبلا .

لقد أنبثقت فكرة اصدار **موسوعة عن بحيرة ناصر**" عندما كان المؤلف الرئيسى ا . حلمى بشاي) مستشارا للوحدة القومية للتنوع البيولوجي ، بإدارة المحميات الطبيعية التابعة لجهاز شئون البيئة برئاسة مجلس الوزراء – خلال التجهيز لدراسة التنوع البيولو ي بمص ر – وذلك بإعداد دراسة عن الموائل المائية – حيث قام مع زميليه ا . سمير عبد الملك ، . مجدى توفيق) بإعداد ثماني مجلدات عن البحيرات المصرية الشمالية البردويل ، المنزلة ، البرلس ، ادكو ، مريوط) والداخلية بحيرة قارون ، بحيرات وادى الريان وبحيرة ناصر).

لقد بذل المؤلفون من الجهد والوقت لتضمين موسوعة بحيرة ناصر نتائج الدراسات المتاحة التى سبق ذكره ، إلا أنه مازال هناك بعض الدراسات والبحوث التى لم نتمكن من الحصول عليها ، لذلك نهيب بالزملاء والباحثين والهيئات العلمية وغيرها بموافاتنا بنتائج تلك الدراسات حتى نتمكن من ضمها في طبعات لاحقة .

وقد تضمنت الموسوعة الحالية نتائج الدراسات التي تمكن المؤلفين ، من الحصول عليها ، وقضوا أكثر من 10 أعوام في جمع وتحليل وتقييم هذه المعلومات التى تشتمل على معظم النواحي وعلى وجه الخصوص البيولوجية منها ومدى تغير التنوع الحيوي منذ تكوين البحيرة حتى الآن ، كذلك ما طرأ على نوعية المياه من تغيير ، مع تخصيص جزء مفصل لاسماك البحيرة ومصايدها وتنميته . أما الهدف الرئيسى لهذه الموسوعة فهو إتاحة الفرصة الكاملة لكل من يهمه الأمر – من بحاث وغيرهم من المهتمين بدراسة البحيرة وادارتها والمخططين وصانعي القرار – لأن يكون سجل كامل عن تطور البحيرة لتكون مرجعا هاما في متناول اليد ، وكذلك لوضع الخطط المستقبلية للبحوث والدراسات ، وحتى التنمية المستدامة له ، والحفاظ عليه ، وادارتها واستغلالها الأمثل المستمر دون الإضرار بالمخزون السمكي به .

ومما لاشك فيه أن الموسوعة الحالية بما تحويه من معلومات كثيرة وفي شتى المجالات سواء قبل أو بعد إنشاء السد العالى قد تكون كافية للتنبؤ بما هو متوقع في مناطق مماثلة مثل منخفض توشكى ، مما يهيء الفرصة للتعرف على الديناميكية الإيكولوجية والتغيرات البيئية ، كما أن تقييم وتحليل نتائج الدراسات بل وأثناء تخزين المياه ستساهم كثيراً في تتبع تطور تلك الخزانات منذ تكوينها وتفهم العمليات المختلفة الناتجة عن تخزين المياه عبر السنين ، وأيضا التعرف على التغيرات المستقبلية لتلك الخزانات ، مما يساعد متخذي القرار والمسؤلين عن الحفاظ على البيئة وادارة تلك المناطق من اتخاذ القرارات الصائبة من أجل التنمية الدائمة مع المحافظة على البيئة ، قبل حدوث مشاكل بيئية قد يصعب أو يستحيل حلها .

وباستعراض تطور بحيرة ناصر منذ باكورة تكوينها نلاحظ أنها مرت بثلاثة أطوار من مراحل التخصيب (eutrophication) :

الطور الأول : **متوسط التخصيب** (mesotrophic– mesohumic) اعتبارا من 1966 إلى 1971 وتراوح الإنتاج السمكى بين 18.01 إلى 27.52 كجم هكتار عام .

الطور الثانى : **متوسط التخصيب – مخصبة** (mesotrophic-eutrophic من عام 1972 إلى 1977 وتراوح الإنتاج السمكى من 31.98 إلى 52.45 كجم هكتار / عام .

الطور الثالث : **مخصبه** (eutrophic اعتبارا من 1978 حتى الآن وتراوح الأنتاج السمكى بين 63.26 إلى 116.99 كجم هكتار عام .

وتم حساب الإنتاجية طبقا لكميات الأسماك التى تسلم لميناء السد العالي ونشرة قسم الإحصاء بالإدارة المركزية لهيئة تنمية بحيرة السد العالي . والجدير بالذكر أنه تم تسجيل أعلى إنتاج سمكى وهو 34206 طناً في عام 1981 بينما في 1998 بلغ الإنتاج السمكى 19203 طن ، وفي الواقع أن الإنتاج

الحق ي للبحيرة غير معروف نظرا لتضارب أرقام الإنتاج السم ي السنوي ، فالإنتاج الذى يعلنــه قســم الإحصاء بالإدارة المركزية للثروة الس مكية ، الهيئة العامة لتنمية بحيرة ناصر يمثل المصيد الفعلي المسلم لميناء السد الع ي وهو المشار إليه في الدراسة الحالية ، ولكن الهيئة العامة لتنمية الثروة السمكية تعلــن تقديرات أعلى من ذلك بكثير بما يربو على 50 % من الإنتاج السمكي الفعلي للبحيــر . و علــل ذلــك ب هريب الأسماك من منافذ غير قانونية لبيعه بأسعار أعلى بكثير من أسعار تسليمها لمو ي الصــيد . أن هذا التضارب في الأرقام يؤدي إلى عدم معرفة الإنتاج الحقيقي للبحير ، وصعوبة بل اســتحالة إجــراء الدراسات على المخزون السمكي من واقع الإنتاج الحقيقي ، كذلك إدارة البحيرة أسلوب علمــي يحــافظ على المخزون السمكي مع عدم استنزاف مصايد البحير . ويوصي المؤلفون بضرورة تحريــر أســعار الأسماك المصيدة من بحيرة ناصر لتخضع للعرض والطلب وآلية السوق ، ولكــن تحــت رقابــة مــن المسئولين ، وهذا يمكننا من معرفة الإنتاج السمكي الحقيقي من بحيرة ناصر .

وتجدر الاشارة الى الدراسة التى قام بها جبر الله (994.) والتى أوضح فيها ان تحديد اســعار اسماك بحيرة ناصر أدى الى لجوء الصيادين لتهريب انتاجهم واستخدام الصيد الجائز بمختلف الاساليب والطرق المخالفه للقانون , ومن ثم استنزاف البحير . كذلك أدى الى عدم تطوير الانتاج والخ دمات الــى الاحدث تكنولوجيا وتقليل القدرة على المنافسة فى الاسواق . وقد قدر الكميات المهربه يوميا بحوالى 50 طن . واوضح أن سياسه التحرير الاقتصادى وتحرير اسعار اسماك بحيرة ناصر يضمن انطلاقه عاجله للتنمية والدخول السريع الى مرحلة التحديث التكنولوجى والانتاجى والا هتمام بمعايير الجودة والكفاء .

ومما لاشك فيه أن نتائج الدراسة الحاليــة ستســاعد البحــاث والمهتمــين بــإدارة البحيــرة والمتخصصين في الدراسات البيئية لوضع الأسس السليمة للتنمية الدائمة للبحيرة مع المحافظــة علــى مصدر المياه الرئيسي لمص ر . ولقد خلصت الدراسة الحالية إلى أن بحيرة ناصر حتى الآن لازالت غير ملوث ، فوجود بعض الكائنات في البحيرة والتى تستخدم كدليل لنقاوة المياه تثبت أن مياه البحيرة نقيــ ، وأن التغير في نوعية مياهها لازال طفيف . كل ذلك يدعو إلى المحافظة على هذا الخزان وحفظه مــن التلوث باتباع أساليب إدارية حازمة مع متابعة مستمرة ورصد أى تغير في البحير ، كما ينادى المؤلفون بضرورة **إعلان منطقة بحيرة ناصر محمية طبيعي** ، تقنن فيها جميع الأنشط . فــالبحيرة عبــارة عــن خزان المياه الذى يمد مصر والمصرين بالحيا ، فإذا تلوثت مياه ، أو ح ت تغيرات جذرية في نوعيــة مياه البحير ، يصبح من المستحيل معالجته ، ولنا عبرة لما حدث في بحيرات مصــر الشــمالي – فــي غياب الو ي البيئي والتخطيط السليم وعدم اتباع الأسلوب الأمثل لحمايته . اذ أصبحت ملوثة مما يهــدد نظامها البيئي بالانهيار ، إضافة إلى ذلك تلوث الكائنات التى تعيش فيها وعلى وجه الخصوص الأسماك – المصدر الرئي ي للبروتين – والذى يتزايد عليه الطلــب باســتمرار ف ي ظــل الزيــادة الســكانية المضطرد ، حتى أصبحت تلك الأسماك مصدرا للأمراض للانسان . ان استعادة تلك البحيرات عافيتهــا أمر حتمي ولكنه محفوف بالمخاطر والصعوبات ، ويلزمه تكاليف هائلة مع إدارة حازم .

وتقع الم وسوعة الحالية فى 13 فصلا ، يتناول **الفصل الأول الخواص الاساسية للبحيــرة** مــن حيث الموقع والقياسات المورفومتريه التى تشمل طول الشاطىء ومســاحة وحجــم الميــاه المختزنــ ، وعرض البحيرة وعمقها عند مناسيب المياه 160 و 180 مترا فوق سطح البحر . وواضــح ان أعمــق

أجزاء البحيرة هو مجرى النيل القدي . وتبلغ سرعة المياه في الجــزء الجنــوبي للبحيــرة مــن 00 – 50 سـ ثانية ، وتقل كلما اتجهنا شمالا لتصل من صفر إلى سـ ثانية . كمــا يســتغرق وصــول ميــاه الفيضان من الجنوب إلى الشمال فترة تتراوح من –12 شهرا ويتوقف ذلــك علــى قــوة الفيضـــان ومنسوب المياه بالبحير .

كما تتميز بحيرة ناصر عن البحيرات لافرية ه الأخرى على وجه الخصوص بطول شــواطئها حيث أن معامل طول الشاطىء يصل إلى 33.1 مقارنه بمتوسط 8. –6.0 للبحيرات الأخــرى . وذلــك لوجود الاخوار ببحيرة ناصر وهي عبارة عن الوديان التى كانت على جا ي البحيرة وغمرتها الميــا . وان كان معظمها ضيقاً ويمتد لمسافات طويلة في الصحراء فالبعض منها متسِ . ويوجد بـــالبحيرة 85 خور ، 48 في الجهة الشرقي ، و37 في الجهة الغربي ، وأكبرها مساحه ي اخوار العلاقـــي وكلابشـــه وتوشكي . وأظهرت الدراسة الحاليه أن الاخوار من أغني الموائل بالبحيرة وتتميز بثرائها في الهائمـــات النباتيه والحيوانية و حياء القاع والنباتات المائي . وتعتبر مناطقها الشاطئية الرملية من أنســب الأمـــاكن لتكاثر سماك البلـ ي و ي السائدة في الانتاجيه الحالية للبحير .

كما تضمن هذا الفصل عرضا شاملاً **لخصائص المياه الطبيعيـــة و الكيميائيـــة والبيولوجيـــة** كدر جه حرارة المياه وشفافيته ، ومدى تأثر تلك الشفافية بالكائنات الحية والمعلقـــات الصـــلبة الدقيقـــة؛ وكمية الأكسجين الذائب وتوزيعه بالنسبة للأعماق وفصول السنـ ، والإنتاجية الأولي ، والتنوع الحيـــوي لكل من الهائمات العوالق) النباتية والحيواني ، وكائنات القا ، وأنوع ا سماك التى تـــم تســـجيلها منـــذ إنشاء البحيرة؛ ومدى التغير في التركيب النوعي لها خلال تطور البحير .

كما يستعرض هذا الفصل ملخصاً عن جيولوجية منطقة البحير ، ومناخها ممثلا فـــي درجـــة حرارة الجو وسرعة واتجاه الرياح والرطوبة النسبية التى تصل إلى أعلاهـــا خـــلال فصـــلي الشـــتاء والربي ، ودرجة التبخر التى أوضحت أن المتوسط اليومى هو 7.3 مليمتر . وقـــد قـــدر كميـــة الميـــاه الفاقدة بالبخر عــــــام 1975 بـــــ 1.6 كم3 وفعليا بـــ 6.4 كم3 (16.4 مليار م3) عند منسوب 180 متر فوق سطح البحر ، تمثل انخفاضاً في منسوب المياه بأكثر من متريز . وقد تضمن هذا لجزء النماذج المختلفة لحساب كمية البخر طبقاً للطرق المتباين .

كما يتناول الفصل الأول مصادر المياه للبحيرة وهى أساسا من هضبة الحبشـــة تمثـــل ا % ، ومن أعالى النيل وتمثل 6 %. والجدير بالذكر ان أعلى فيضان خلال القرن الحالي كـــان عـــام 1998 حيث وصل أعلى منسوب للمياه البحيرة 181.3 متر ، فوق سطح البحر تبعه فيضان 1999 وهو أيضا فيضان عال أعلى منسوب حوالى 181.60 متر). وعزي ذلك إلى الأمطار الغزيرة التى سقطت علـــى منطقة الخرطوم وغرب السودان . وفي حزام منطقة السهل الممتد من سهول كردفان في الغـــرب إلـــى سهول منطقة كسلا في الشرق . وتـ تبر هذه ظاهرة نادرة يرى بعض المختصين أنها لا تحدث إلا كـــل بضعة مئة عا . ولعل التغيرات المناخية العالمية لها تأثير في ذلك . ويجدر بالذكر أن هضـــبة الحبشـــة أصابها جفاف نسبي خلال العامين الماضيين ، حتى أن حكومات ـ نيا واثيوبيا طلبت المساعدة العالميـــة من وكالات الغوث .

ولما كانت ديناميكية الترسيب في البحيرة من المتغيرات الأساسية الناتجة من تكوين بحيرة السد العالي لذلك يتناول **الفصل الثانى** كميات **الرواسب** ونوعيتها وخواصها في المناطق المختلفة للبحيرة على امتدادها ، والتي أوضحت أن معظم الرواسب التي تحملها مياه الفيضان تترسب في بحيرة النوبة منطقة جومي والجندل الثانى بالقرب من وادى حلفا) حيث تراوح سمك الرواسب حتى عام 1975 حوالى 7 و20 متراً على التوالي ، مقارنة بحوالى متر واحد عند أدندان داخل حدود مصر كما أشارت الدراسات أن معظم الرواسب من الغرين .

ويتوقف معدل الترسيب على عده عوامل منها : البيئة ، كمية مياه الفيضان ، مستوى المياه في البحيرة ، وفترة توزيع مياه الفيضان . كما يشمل هذا الفصل طبيعة المواد المترسبة في كل من بحيرتي النوبة وناصر ، ومدى تأثير العوامل البيئية عليها .

والجدير بالذكر أن مياه الفيضان قبل إنشاء السد العالي كانت تحمل كمية من الغرين (silt) تعادل حوالى 125 مليون طن سنويا ، يترسب منها 0 –5 % في المناطق الزراعية بمصر العليا وقاع النيل حتى شمال القاهرة ونسبة مماثلة تترسب على أراضى الدلتا الزراعية ، أما النسبة الأكبر فكانت تترسب حول شواطئ رشيد ودمياط ، أما الباقي فيترسب على الرصيف القاري . وبعد إنشاء السد العالي فان كمية الغرين التى تصل إلى البحيرة لا تتجاوز 0.1 – 10 مليجرام/ لتر ، وحاليا تبلغ كمية الغرين من 10 إلى 132 مليجرام/ لتر أي حوالى 0.1 كم3 غرين/ العام) معظمها من المواد العضوية .

كما أشارت الدراسات أن هناك علاقة بين نوعية الرواسب ودرجة تركيز الكالسيوم والكربونات والمادة العضوية والإنتاجية الأولية . كما وجد أن المواد العضوية تزداد في الشتاء في المجرى الرئيسي وجانبي البحيرة كليهما .

وأوضحت النتائج أن تركيز المعادن الثقيلة نحاس ، زنك ، منجنيز ، حديد) في رسوبيات بحيرة ناصر أعلى منها في نهر النيل شمال السد العالي . كما أن تركيز النحاس يكون أعلى في بحيرة ناصر منه في بحيرة النوبة . كما أن هناك علاقة بين محتوى النحاس في رواسب البحيرة والعمق ، وحجم حبيبات الرسوبيات والمحتوى العضوي . كما سجلت زيادة في تركيز الزنك تصل إلى اقصاها في منطقة أبو سمبل ثم تنخفض عند أدندان ويستمر الانخفاض حتى جنوب بحيرة ناصر . كما اتضح أن هناك تغيرات في تركيز كل من المنجنيز والحديد والزنك وقد نوقشت الأسباب التى تؤدي إلى تلك التغيرات .

ويستعرض **الفصل الثالث البيئة الطبيعية** للبحيرة منذ تكوينها حتى الآن والتى تشمل درجة حرارة المياه السطحية والتى تماثل تقريبا درجة حرارة الجو ولكنها تنخفض خلال فصل الصيف نتيجة للبخر . وسجلت أعلى درجة حرارة للمياه السطحية خلال شهر أغسطس وأقل حرارة خلال شهر ديسمبر . كما تختلف درجه حرارة المياه طبقاً للمناطق والأعماق والفصول .

وتتميز بحيرة ناصر بظاهرة الطبقات الحرارية (thermal stratification) والتى تبدأ في أواخر الربيع وتستمر خلال الصيف حتى الخريف ، وقد يصل الفرق بين درجة حرارة المياه السطحية والمياه عند القاع إلى 3.75 . .

وتتغير درجة شفافية الماء طبقا للمناطق وفصول السنة ، ومن الملاحظ أن جنوب البحيرة أقل شفافية من شمالها . وأن مياه الأخوار أقل شفافية من المياه في المجرى الرئيسي , وشملت الدراسة مقارنة لدرجة الشفافية في بحيرتي النوبة وناصر والعوامل المؤثرة فيها سواء من مياه الفيضان ، أو من المواد الصلبة أو الهائمات . وقد سجلت أعلى قيمة لشفافية المياه في فصل الشتاء متوسط 75 سم ، بينما تقل الشفافية في فصلي الربيع والصيف وذلك في المجرى الرئيسي والأخوار . وعموما فالأخوار الجنوبية أقل شفافية من الأخوار الشمالية . كما تلعب المعلقات الصلبة الدقيقة والهائمات دوراً هاماً في تحديد درجه شفافية المياه .

والجدير بالذكر أن هبوب رياح مستمرة من الشاطئ يؤدى إلى خلق تيارات مائية صاعدة تحمل المياه الرائقة والفقيرة في الهائمات من المياه العميقة إلى المياه السطحية مما يؤدي إلى ارتفاع شفافية الماء حتى تصل أحيانا إلى 7.4 متراً أو أكثر . وبعد بضعة أيام من الطقس الساكن تنخفض درجة الشفافية بسبب نمو الهائمات النباتية .

ويتناول **الفصل الرابع دراسة البيئة الكيميائية للبحيرة** وتشمل كميه الأكسجين الذائب في الماء ، ودرجه التوصيل الكهربي ، وقيمه الأس الأيدروجيني ، ودرجة القاعدية ، والأيونات الأساسية السالبة والموجبة) وكمية الأملاح الذائبة في الماء ، والأملاح المغذية وعلى وجه الخصوص النترات والفوسفات .

وقد لوحظ أن كمية الأكسجين الذائبة في مياه البحيرة تتغير طبقا للفصول والمناطق والأعماق . وتتراوح درجة تركيز الأكسجين الذائب عند السطح من 150 إلى 00 % من درجه التشبع ، نتيجة عملية البناء الضوئي للهائمات النباتية الموجودة في المياه السطحية بكثافات عالية . كما تتميز بحيرة ناصر بظاهرة الطبقات الأكسيجينية (oxygen stratification) المصاحبة لظاهرة الطبقات الحرارية . حيث تكون الطبقات المائية العليا أغنى فى الأكسجين الذائب منها في الطبقات السفلية ، حتى تخلو المياه عند قاع البحيرة تماماً من الأكسجين . وقد تم تسجيل انعدام الأكسجين في طبقات المياه العميقة أثناء فترة الطبقات الحراريه في الصيف . وقد لوحظ أن الطبقات العليا ذات التركيز العالي للأكسجين تكون أكثر سمكا في المناطق الجنوبية عنها في الشمالية . كما أن متوسط كمية الأكسجين الذائب في الماء على جانبي البحيرة أعلى مما هو في المجرى الرئيسي ، ويكون تركيز الأكسجين في الماء أعلى في الجانب الغربي من البحيرة منه في الجانب الشرقي .

ومن الدراسات الهامة لنوعية المياه هي **درجة التوصيل الكهربي** التى تعطي مؤشرا عن كمية الأملاح الذائبة في مياه البحيرة منذ بدأ تكونها حتى الآن . وقد تراوحت درجة التوصيل الكهربي من 155 الي299 $\mu mhos\ cm^{-1}$ ، وتتغير طبقاً للفصول والمناطق والأعماق . ويتوقف التغير في درجه التوصيل الكهربي على تحركات مياه الفيضان – والتى يمكن بواسطتها تتبع هذه المياه من جنوب إلى شمال البحيرة – وقد سجلت أعلى قيمة لدرجة التوصيل الكهربي أمام مياه الفيضان . ولما كانت معظم مياه الفيضان تنبع من النيل الأزرق ذى درجه التوصيل الكهربي المنخفض ، لذلك نجد أن درجة التوصيل الكهربي للبحيرة منخفضة .

ومن الملاحظ أن قيمة التوصيل الكهربي للمياه السطحية منخفضة حوالى 55 µmhos cm^{-1} في خور كلابشه ، بينما تكون عند القاع مرتفعة (290 µmhos cm^{-1}). كما تزداد درجة التوصيل الكهربي لمياه الأخوار من الجنوب للشمال . وخلصت الدراسة الحالية إلي أن درجة التوصيل الكهربي بالبحيرة – وان كانت تتأرجح صعودا وهبوط ، على مدار العام وطبقا للأعماق وفى الأعوام المختلفة ولكنها لم تتغير كثيراً منذ بدء تكوين البحيرة حتى الآن .

وباستعراض الدراسات عن **قيمة الأس الأيدروجيني** (pH) لمياه البحيرة منذ تكوينها حتى الآن وجد أنها لم تتغير بدرجة محسوسة ، إذ تراوحت في المياه السطحية من 7.8 إلي 9.6 ، وفي المياه القاعية من 6.8 إلى 8.6 . و عزى انخفاض درجة الأس الأيدروجيني عند القاع في السنوات الأخيرة إلى تكوين غاز ثانى أكسيد الكربون الذي قد يصل إلى 3,3 مليجرام/ لتر في بعض المناطق ، علما بأنه لم يسجل أي تركيز لهذا الغاز في المياه القاعية في السنوات الأولى من تكوين البحيرة .

و عزى **قاعدية** (alkalinity) مياه البحيرة إلى البيكربونات بصورة أساسية حيث أن **تركيز الكربونات** محدود . ففي السنوات الأولى لتكوين البحيرة سجلت تراكيز للكربونات في المياه السطحية تتراوح من صفر إلي 28 ملج/ لتر . وفى عام 1992 تراوحت من صفر إلي 32 ملج/ لتر بمتوسط 15 ملج/ لتر ، وفى عام 1995 تراوح تركيز الكربونات من صفر إلى 28 ملج/ لتر ، وسجل أعلى تركيز في مياه القاع لخور كلابشه . وسجلت القيم العليا في الثلاثة أمتار السطحية مقارنة بأعماق 15 متراً وعند القاع . ومن الواضح أن تركيز الكربونات بالبحيرة لم يتغير منذ بدء تكوينه .

أما **تركيز البيكربونات** فقد كان أعلى منه للكربونات كثير ، ففي عام 1970 تراوح من 130 إلى 181 ملج/ لتر ، مقارنة بمدى يتراوح من 117 إلي 203.4 ملج/ لتر فى عام 1974/ 1975 . وفى عام 1993/ 1994 كان تركيز البيكربونات يتراوح من 96.8 إلي 129.5 ملج/ لتر وسجلت أقل قيم في الصيف . أما في عام 1995 فقد تراوح من 8 إلي 200 ملج/ لتر . وواضح من استعراض تلك النتائج أن تركيز البيكربونات في البحيرة لم يتغير كثيراً منذ تكوين البحيرة حتى الآن ، مع تغيرات طبقاً للمناطق والأعماق والفصول .

وقد تراوح تركيز **الأيونات الأساسية** في المياه : صوديوم ، بوتاسيوم ، كالسيوم ، منجنيز من 6.2 إلي 27.8 ؛ 1.9 إلي 8.1 ؛ 14 إلي 27.2 ؛ 4.5 إلي 12.5 ملج/ لتر على التوالي . أما تركيز الكبريتات فلم يتغير كثيراً منذ تكوين البحيرة حتى الآن حيث يتراوح من 5 إلي 15 ملج/ لتر . وقد عزى المحتوى المنخفض للكبريتات في المياه العميقه الي قلة الأكسجين الذائب مما يؤدى إلى نشاط البكتريا المختزلة للكبريت وتكون غاز كبريتيد الأيدروجين . وقد سجل عبد المنعم (1995) علاقة بين تركيز الكبريتات وكلورفيل أ ، مما يؤيد الرأى القائل بان نمو الهائمات النباتية يتأثر بتركيز الكبريتات في البحيرات ألافريقية الاخرى .

وباستعراض **التركيز الكلي للأملاح الذائبة** (total dissolved solids) في بحيرة ناصر منذ تكوينها نلاحظ أنها لم تتغير كثيراً منذ نشأتها للآن ، بعكس توقعات سابقة بان نوعية مياه بحيرة ناصر سترتفع بها كمية الأملاح الذائبة نتيجة للتخزين . ففي عام 1970 تراوح التركيز الكلي للأملاح الذائبة من 69 إلى 195 ملج/ لتر ، وفي عام 1982/ 83 تراوح من 130 الي 180 ملج/ لتر ، وفي عام

985 /1986 تراوح من 131 الي 171 ملج لتر ، وفي عام 1998 سجل تركيز يتراوح من 140 إلى 160 ملج لتر .

وتعتبر بحيرة ناصر من أغنى البحيرات في **الأملاح المغذيـــة** (nutrient salts) فوســـفات ، نترات ، اذا قورنت بالبحيرات الأفريقية الصناعية الثلاث فولتا ، كاريبا ، كاينجي). فقد تراوح تراكيـــز كل من الفوسفات الذائب ، نتروجين النترات (NO_3-N) ، والسيلكون في بحيرة ناصر مـــن 0.02 إلـــي 0.52 ؛ صفر إلي 3.0 ؛ 10 إلي 35 ملج لتر على التوالي . أمـــا كميـــة النتـــروجين الكليـــة (total nitrogen) فقد تراوحت من 1.41 إلى 14.5 ملج لتر . وقد أظهرت الدراسات أن تركيـــز الفوســـفات الذائب لم يتغير تغيراً محسوساً منذ تكوين البحير ، وأن كان تركيزه يتأرجح من منطقة إلـــى أخـــرى ، وطبقا للأعماق وفصول العام ، وكثافة الهائمات النباتية . أما بالنسبة للأملاح المغذية الأخرى كالنترات ، والسيلكا وغيره) فالدراسات عليها محدودة لذلك لم نتمكن من تتبع أى تغيرات في تركيزها منذ تكـــوين البحير .

ويتضمن **الفصل الخامس عرضا لنباتـــات** (flora) البحيرة وتشمل دراسات عن النباتات المائية الكبيرة (euhydrophytes) والطحالب (algae) والفطريات(fungi) والبكتريـــا bacteria . وتجـــدر الإشارة لأهمية النباتات كمصدر الإنتاجية الأولية (primary productivity) في البحير ، وعلى وجه الخصوص النباتات المائية الكبيرة والتى يتسبب وجودها بكثافات عالية في فقد كميات كبيرة من الميـــاه عن طريق النتح ، تفوق تلك الكمية التى تفقد بواسطة البخر الطبيعي . لذا كان لوجود النباتـــات المائيـــة الكبيرة فـــي البحيرات أهميـــة خاصه ، فمثلا وجـــود ياسنت المـــاء ورد النيل) (water hyacinth) في البحيرات يعتبر آفة يصعب التخلص منها لقدرته الفائقة على لتكاثر ، لذلك يجـــب مراقبـــة البحيـــرة باستمرار ورصد أى نباتات دخيلة اليه ، وليس ببعيد غزو الياسنت المائى لجنوب السودان فـــى أواخـــر الخمسينات وقد أصبح آفة يصعب التخلص منها على طول مجرى نهر النيل من جنوبه لشماله .

وقد سُجل 11 نوعاً من **النباتات المائية الكبيرة** (macrohydrophytes) من منطقـــة النوبـــة المصرية قبل إنشاء السد العالي ، اختفى منها نوعان . كما لـــوحظ أن 3 أنـــواع مـــن نبـــات الحـــريش الحامول ، نير) *Potamogeton* spp. والتى تم تسجيلها في البحيرة في السبعينات اختفت تمامـــاً منهـــا في الوقت الحاضر . وتتوزع النباتات المائية الكبيرة في البحيرة طبقا لنوع التربـــة والأعمـــاق وأحيانـــا المنطقة . وقد تم مناقشه أثر انحسار المياه في المنطقة الشاطئية على نوعية وتوزيع النباتات المائية ، مع التعرف على أثر الظروف البيئية على انتشارها وكثافتها .

وحتى الآن لم يظهر في البحيرة نباتات مائية خطيرة مثل ياسنت الماء ورد النيل) المنتشر في نهر النيل سواء جنوب أو شمال البحير . ونظراً لخطورة هذا النبات على البحيرة لذلك يرى المؤلفـــون ضرورة الرصد المستمر للنباتات المائية ، كما يجب تحذير الصيادين وغيرهم من رواد البحيرة بالإبلاغ فوراً عن ظهور أى نوع غريب ، مع أتخاذ الاستعداد الكافي بإعداد أجهزة المقاومة للقضـــاء علـــى أى نبات غير مرغوب فيه قبل انتشاره في البحير .

وبالرغم أن السد العالي يعتبر حاجزاً ضد أى انتشار للنباتات المائية من شمال الس ، ففي أوائل التسعينات ظهر نبات الحزبيل ذو الالف ورق) *(Myriophyllum spicatum)* في بحيرة ناصر ، وقد سر وجود هذا النبات إلى استخدام الصيادين العاملين في بحيرة ناصر شباكاً لصيد الأسماك سبق استخدامها في النيل شمال السد العالي حيث يكثر هذا النبات الذى علق بهذه الشباك ومنها انتقل للبحير . أن المراقبة المستمرة والتوعية للصيادين ومستخدمي البحيرة بتحذيرهم من نقل أي نبات مائي اليها أمر حتمي .

في المراحل المبكرة من تكون بحيرة ناصر عام 971) تم تسجيل 27 نوعا من **الهائمات العوالق) النباتيه** (phytoplankton) بينما في القترة من 1982 إلى 1993 س ـ ل 135 نو ـ ا من الطحالب تنتمي إلى 5 فصائل : طحالب خضراء (Chlorophyceae) (54 نوع ، طحالب خضراء مزرقة (Cyanophyceae) (34 نوع ، دياتومات Bacillariophyceae (33 نوع ، ثنائية الأسواط (Dinophyceae) (13 نوع ، طحالب يوجلينية (Euglenophyceae) نوع واحد).

ومن الملاحظ أن عشائر الهائمات النباتية غنية من حيث الكثافة والكتلة الحيوية ويزداد محصولها الكلي كلما اتجهنا إلى جنوب البحيرة حيث تصل إلى 15.272 × 10 وحدة طحلب في اللتر الواحد في منطقة أدنداز ، وبينما يزداد عدد الهائمات النباتية بالقرب من سطح المياه في البحيرة يقل العدد كلما ازداد العمق ، وكان المتوسط السنوي للكتلة الحيوية للطحالب عند سطح المياه وعلى عمق 20 مترا 2.913 ؛ 4.088 ملجـ لتر على التوالي .

وتمثل الدياتومات والطحالب الخضراء المزرقة البكتريا الزرقاء Cyanobacteria) المجاميع السائدة في مياه البحيرة ويختلف توزيعها في المياه تبعا لفصول العام والمناطق والأعماق ، وتسود الدياتومات على الطحالب الخضراء المزرقة على طول المجرى الرئيسي لبحيرة ناصر مما يدل على تأقلمها للظروف البيئية للبحير .

كما سجلت علاقة عكسية بين كثافة الطحالب ودرجة تركيز نتروجين – نترات(NO_3-N) ، كما أن كثافة الطحالب في الأخوار أعلى منها في المجرى الرئيسي للبحير ، وإن الأخوار التى تقع في جنوب البحيرة أغنى في كثافة الطحالب من تلك التى تقع في شمال البحير .

ومن الظواهر الهامة التى سجلت في البحيرة في أوائل تكوينها هي ظاهرة **الأزدهار الطحلبي**(algal blooms) نتيجة لنمو وتكاثر كثيف لبعض أنواع الطحالب الخضراء المزرقة خاصة نوع يسى ميكروسستس أريجانوزا *(Microcystis aeruginosa)* و الانابينا *(Anabaena* sp.) و ي الأنواع السائدة في كل الظروف ، وهي طحالب سامه . وفي بداية تكون البحيرة سجلت هذه الظاهرة في فترات محدودة وعلى مساحات صغيرة في جنوب البحيرة قبل موسم الفيضان ، حيث يكون نمو الطحالب غزراً مما يؤدى إلى موتها وتحللها واستهلاكها للأكسجين الذائب في الماء مما يؤدى إلي نقص الأكسجين في الميا . إلا أنه في السنوات الأخيرة لوحظ حدوث الازدهار الطحلبي في كل مناطق البحيرة وعلى مدار العا ، الأمر ا ي يستد ي مراقبة مستمر ورصد هذه الظاهرة ومتابعتها ودراستها للتعرف على ما تسببه من تغيرات في نوعيه المياه ومدى تأثيرها على الأسماك . أن من أهم العوامل المسببة للازدهار الطحلبي هو زيادة التخصيب بالأملاح المغذيه . وهو أمر متوقع في بحيرة

ناصر وخاصة بعد انتشار الزراعات الشاطئية واستخدام المخصبات . ففي السنوات الأخيرة تم زراعة الآف الأفدنة من خلال برنامج مشترك بين الهيئة العامة لتنمية بحيره ناصر وبرنامج الغذاء العالمي ، دون الاخذ في الاعتبار تأثير استخدام المخصبات علي مياه البحير . وقد بلغت مساحة الأراضي الشاطئية التي تزرع بالحبوب والخضروات والفاكهة حوالى 10860 فدنا اضافه الي 192 فداناً تزرع خضروات واشجار فاكهة في الفتره من 1989 الي 996 .

وقد اوضحت الدراسات أن أعلى قيمه **لكلوروفيل** " **للهائمات النباتية** (phytoplankton) يكون في المناطق الجنوبية للبحير ، وعلى وجه الخصوص في الأخوار . كما أن تركيز كلوروفيل " في الأخوار يتبع مثيله في المجرى الرئيسي للبحيرة حيث يصل لذروته في الربيع والصيف ، وأدنى قيمة له في الشتا . كما لم تسجل تغيرات محسوسة في تركيز كلوروفيل " داخل أو خارج أو عند مداخل الأخوار ، ما عدا خلال فصل الربيع حيث لوحظت تغيرات محسوس . ويصل تركيز كلوروفيل " في الد حالب الموجودة عند أعماق 2 الى 4 أمتار الى أعلى قيم ، ثم يقل تدريجيا مع زيادة العمق . وفي المجرى الرئيسي للبحيرة والأخوار تزيد قيم كلوروفيل " في الشهور ي تكون فيها درجة حرارة الماء مرتفع ، وتنخفض في الأشهر ذات درجة الحرارة المنخفض ، ويصاحب ذلك تغيرات في شفافية مياه البحير .

وفي دراسة حديثة وُجد أن **النانوبلانكتون الهائمات الدقيقة جد)** (nanoplankton) يحتوي على التركيز الأكبر من كلوروفيل " إذا قورن بتركيزه في الطحالب التى تجمع بالشباك (net plankton) . وقد سجلت أعلى القيم لكلوروفيل " ي النانوبلانكتون و لطحالب التى تُجمع بالشباك في الربيع ، وأدناها في الشتا ، كما سجلت تغيرات لكلوروفيل " ا نانوبلانكتون تبعا لاختلاف المناطق والأعماق والفصول . والجدير بالذكر أن تركيز كلوروفيل " في النانوبلانكتون كان مرتفعاً في جنوب البحيرة عن تلك التى ي شمالها ، ولكن الـ كس كان صحيحاً فى الربيع .

أوضحت الدراسات ايضاً أن **الإنتاجية الأولية** (primary productivity) لبحيرة ناصر عالية نظراً لثرائها بالأملاح المغذي ، وتصل قيمة الإنتاجية الأولية إلى أقصاها عند عمق من متر إلى 3 متر ، وتتراوح الإنتاجية الأولية الكلية بين 3.2 و 5.3 جرا ك م/ يو ، وفي دراسة حديثة بينت أنه في الربيع تراوحت الإنتاجية الأولية في المجرى الرئي ي للبحيرة وعلى عمق 3 متر بين 179.91 ملج ك م/ ساعة فى منطقة دهميت إلى 2.87 ملج ك م/ ساعة ي منطقة آماد ، وإن أعلى متوسط للقيمة الإنتاجية الأولية (8.8 ملج ك م/ ساع) يكون ف ي فصل الربيع بينما أقلها (2.39 ملج ك م/ ساع) يكون ي الشتا ، وتعزى الزيادة التدريجية ي الإنتاجية الأولية لبحيرة ناصر إلى الترسيب المستمر للمواد العضوية الغنية بالأملاح المغذية و ي تتجمع عاما بعد خر مع مياه الفيضان .

وتمثل **الطحالب العالقة الثابت .)** (attached microalgae-epiphytes) غذاءاً أساسياً للبلطيات و ي الأنواع السائدة في البحير) ي بداية تكوين البحيرة تم تسجيل 14 نوع ، وفي دراسة لاحقة ومتكاملة أمكن تسجيل 28 نوعاً تنتمي الى : الدياتومات ، والطحالب الخضرا ، والطحالب الخضراء المزر ه وثنائيات الأسواط دينوفلاجلات). وقد كانت الأجناس السائدة اودوجونيم *Oedogonium)* ، استجيكلونيم *(Stigeoclonium)* ، والاسبيروجيرا *(Spirogyra)* . وقد سجلت

أعلى قيم لكلوروفيل ' للطحالب العالقة في العينات التى تسود فيها الطحالــب الخضــرا . أمــا القــيم المنخفضة فتوجد في العينات الفقيرة في الطحالب الخضراء والخضــراء المزرقــ . كمــا لــوحظ أن الاسبيروجيرا تتواجد بصفة رئيسيه في جنوب البحيرة أبو ســمبل وتوشــكى) وقــد تراوحــت قيمــه كلوروفيل ' للطحالب العالقة من 10.9 إلي 78.0 ملج م . وقد قدرت كمية الطحالب العالقــة بطــول شاطىء البحيرة عند منسوب 160 متراً بحوالى 421.4 طن في شهر ديسمبر 1989 متوســط قيمــة منطقتى أبو سمبل وتوشكى).

تم تحديد 25 نوعا **من الفطريات المائية** (aquatic phycomycetes) المعروفة في الميــاه السطحية لبحيرة ناصر ، أربعة أنواع منها لم يتم التعرف عليه . وتنتمي أنواع الفطريات إلى 11 جنس ، وكانت عينات المياه الغنية بالفطريات المائية ذات درجة حــرارة منخفضــة (15.9 – 20.3) وأس يدروجيني من 7.4 إلى 8.3 وكمية أكسجين ذائب تتراوح من 5.2 إلى 9.3 ملج لتر، وأمــلاح كليــه ذائبة من 208.0 إلى 254.0 ملج لتر ، أما عينات المياه الفقيرة بالفطريات المائية كانت ذات درجــات حرارة مرتفعه تتراوح من 20.6 إلى 31.3 م ودرجة أس الهيــدروجينى 5.3 – 8.2 ، والأكســجين ذائب من 4.5 إلى 10.6 ملج لتر ، والأملاح الكلية الذائبة من 149 إلى 303 ملج لتر ، وقــد كانــت أجناس سابروليجنيا *(Saprolegnia)* وبيثيام *(Pythium)* هما أكثر الأجناس شيوعا .

ومن الملاحظ وجود تغيرات رأسية واضحة في عشائر الفطريات المائية وسجل أعلــى عــدد منها في المياه السطحية بسبب تزايد في اعداد سبيرجيللس فيموجاتوس *(Aspergillus fumigatus)* ، تيرييس *(A. terreus)* . ثم يقل عدد الفطريات حتى عمق 30 متراً وبعد ذلك يزداد العــدد تــدرجيا ليصل إلى ذروته عند عمق 70 متر ، ويعزى ذلك إلى الزيادة الكبيرة في عدد بنيسليوم فيونيكولوســوم *(Penicillium funiculosum)* .

وأوضحت دراسة **الفطريات الميزوفيلية الوسطية** (mesophilic fungi) التى جمعت مــن المياه عند حافة البحيرة والطين المغمور بأن أعلى قيمة لها تكون في شهر أكتوبر أو ديسمبر أو فبراير . وتتميز عينات الطين المغمور والغنية بالفطريات المائية بأس أيدروجينى قاعدى (7.6 – 7.9 ، وتراكيز منخفضة للأملاح الكلية الذائبة (1.9 – 2.9 ملج /100 جرام من الطين ؛ ومحتوى عضــوى مــنخفض (0.4 – 1.6 ملج /100 جم من الطين). وأن أجناس الفطريات المائية السائدة هي بــايثيوم *Pythium* وسابروليجنا *Saprolegina* .

وباستعراض **الدراسات البكترلوجية** على بحيرة ناصر منذ عام 1974 حتى 1998 ، وجــد أن هناك تغيرات طبقا للمناطق والفصول والأعوام المختلف . ففى عامي 1974 و 1984 سجلت أدنى قيمة للأعداد الكلية للبكتريا (TBC) فى درجتي 22 و 37 م في فصل الشتاء ، وأعلى قيمة لها في فصــل الصيف . كما وجد انخفاض تدريجى للأعداد الكلية للبكتريا كلما اتجهنا من جنوب البحيرة الى شــمالها ، مع أعلى قيمه لها في المنطقة القريبة من السد العالي . وقد سجلت زيادة محسوسة للأعداد الكلية للبكتريا عام 1984 عن تلك التى سجلت في عام 1974 .

ومن الملاحظ أن الأعداد الكلية للبكتريا فى عام 1996 عند درجتى 22 و37 م كانت أكثر الف مرة منها فى عام 984. كما أ ها كانت أعلى ما يمكن ي الربيع ي كل مناطق البحيرة سواء فى المجرى الرئي ي أو الاخوار . بينما أقل ة سجلت ي الخريف مع ملاحظة عدم وجود ي بيانات عن فصل الصيف). و ي الأخوار نجد أن العدد ال ي للبكتريا ي فصل الشتاء أعلى منه ي المجرى الرئي ي للبحير .

وباستعراض النسبة بين العدد الك ي للبكتريا عند درجه 2 م الى تلك عند 37 م نلاحظ أنها أعلى من واحد ع تغيرات بسيطة وعلى وجه الخصوص خلال السنوات الأولى لتكوين البحير ، وهذا مؤشر يدل على أن مياه بحيرة ناصر غير ملو ة حتى الآ . ولكن الزيادة الهائلة ي الأعداد الكلية للبكتريا عاماً بعد عا ، وعلى وجه الخصوص ي الأعوام الأخيرة تعتبر مؤشرا على إمكانية زيادة تلوث البحيرة من خلال النشاط البش ي مما يستد ي أخذ احتياطات مشددة لعدم صرف اي مخلفات ي البحير .

وقد وجد أن أعداد البكتريا غير التكافلية المثبتة للنتروجين (asymbiotic nitrogen fixers) والبكتريا الهوائية (aerobes) ، والازوتوباكتر *(Azotobacter)* ، واللاهوائيه (anaerobes) تميل الى الانخفاض عام 1984 عنها منذ 10 أعوا مضت ، وقد ع ي ذلك الى فترة الجفاف وقلة المعلق ات التى تصل مع مياه الفيضان التى تحمل هذه الكائنات معه .

كما أظهرت أعداد بكتريا التأزت (nitrifying bacteria) زيادة ملحوظة فى عام 1984 إذا قورنت عام 1974 وصاحب ذلك زيادة ي نشاطها التأزتي . وقد أدى ذلك إلى زيادة محتوى النترات لمياه البحيرة بعد فترة الجفاف . ومن دلائل زيادة تخصيب البحيرة هو الزيادة الملحوظة فى قيمة الأس الايدروجيني عام 1984 مقارنه عام 974 .

كذلك سجلت أربعه أجناس وثمانية أنواع من **البكتريا القرمزية غير الكبريتية** (purple nonsulphur bacteria) وقد كان أكثرها شيوعاً جنس رودوسيدوموناس *(Rhodopseudomonas)* ي كل المواقع وا ي كان ممثلا بثلاثة أنواع . ويل ي الجنس السابق ذكره رودوميكروبيوم *(Rhodomicrobium)* وا ي كان ممثلا بنوع واحد هو ر فين ي *(R. vannielli)* وا ي سجل ي أخوار البحيرة فقد . ولقد لوحظ أن الاخوار أغنى ي عدد أجناس البكتريا غير الكبريتية بالمقارنة بالمجرى الرئي ي للبحير .

إن الدراسة المتاحة عن بكتريا القولون والبرازية و التى أجريت عام 996 ، أوضحت أنها كانت أعلى ما يمكن ي فصل الشتاء بالقرب من الس د الع ي مقار ة بتلك التى سجلت ف ي مناطق أخرى ، بينما كانت أدناها ي فصل الخريف . لم تسجل ي بيانات خلال الصيف) ولوحظ أن أعداد البكتريا القولونية والبرازية ي الأخوار كانت أعلى عند القاع عنها عند سطح الما . كما أن بعض الأخوار مثل خور كلابشه كان خ ليا من نو ي البكتري .

ويرى المؤلفون ضرورة إجراء دراسات تفصيلية عن البكتريا بأنواعها على امتداد مجرى البحيرة والأخوار وخاصة بعد زيادة النشاط البش ي ي البحير ، ممثلا ف ي الصيادين والبواخر السياحي ، واحتمال صرف المخلفات الصحية بالبحيرة دون رقاب ، مما يؤدى إلى تلوثه . ل لك يجب

اتخاذ إجراءات مشددة نحو عدم إلقاء أي مخلفات للصرف الصحي من قبل الصيادين أو البواخر السياحية أو إلقاء فضلات تصنيع الأسماك ؛ خاصد ، وقد بينت الدراسات أن أعداد البكتريا الكلية تكون أعلى ما يمكن ي منطقة السد العالي .

ويتضمن **الفصل السادس** دراسة **الهائمات الحيوانية وحيوانات القاع** ، ومدى تطورها منذ تكوين البحيرة حتى الآن . فقد سجل 79 نوعا من الهائمات الحيوانية في البحيرة، تنتمى إلى 35 فصيلة وأن المناطق الجنوبية من البحيرة أكثر كثافة ي الهائمات الحيوانية تتراوح بين 233.9 × 10^3 و 562.1 × 10^3 كائن م^3 ي ي سمبل) من المناطق الشمالية للبحيرة حيث تتراوح بين 52.9 × 10^3 و 156.4 × 10^3 كائن م^3 . وإذا قورنت كثافة الهائمات الحيوانية ببحيرة ناصر بتلك التي توجد في بحيرات مصر الأخرى نجد أنها أعلاها مما يدل على خصوبة العالية لبحيرة ناصر .

أما بخصوص الوزن الرطب للهائمات الحيوانية ففي الفترة من يوليو إلى ديسمبر 1990 نجد أنه يتراوح بين 210 و 1940 ملجم م^3 ي جنوب البحير ، ومن 50 – 980 ملجم م^3 في شمال البحير . كما لوحظ زيادة تركيز كلورفيل " مع ارتفاع عدد الهائمات الحيوانية فى جنوب البحيرة خاصة عند العلاقى وكورسكو وتوشكى . والجدير بالذكر أن معظم الدراسات ي تمت على الهائمات الحيوانية بنيت على أساس فحص عينات محدودة ي أوقات ومناطق محدودة ولكنها تعطي صورة عن توزيع وكثافة الهائمات الحيوانية والتنوع الحيوي لها بالبحير ، وإن دراسة تفصيلية متكاملة لازمة للتعرف على الصورة الواقعية له .

و كون مجدافية الأقدام (Copepoda) ، ومتفرعة القرون (Cladocera) ، والعجليات (Rotifera) المجموعات الرئيسية للهائمات الحيوانية ي بحيرة ناصر ، وقد سجل أعلى تركيز في أعدادها عند عمق من 5 إلى 10 أمتار ما عدا ي منطقة كلابشة حيث سجلت أعلى كثافة عند عمق 15 متر . وإن أعلى كثافة للهائمات الحيوانية كانت خلال الشهور ذات درجة الحرارة المنخفضة الشتاء ، وأدناها خلال الصيف عندما تكون درجة الحرارة عالية بعكس ما نجده مع درجة تركيز كلوروفيل ".

وفي الأخوار تم التعرف على 40 نوعاً من الهائمات الحيوانية تشمل أساسا مجدافية الأقدام ، ومتفرعة القرون والعجليات ، وتحتوى المناطق الشاطئية للأخوار على الهائمات الحيوانية طيلة العام مع ذروة ي الكثافة خلال الشتاء ثم الربيع ، وتصل إلى أدنى قيمة لها ي فصل الصيف ، ثم تزداد تدريجيا خلال الخريف ، كما سجل أعلى محصول ي للهائمات الحيوانية عند عمق 5 أمتار وأدنى قيمة له عند عمق 20 متر .

وقد تم التعرف على 59 نوعا من **الأحياء القاعية** (benthos) تنتمي إلى تسعة طوائف ، كانت مجموعة الحشرات فيها السائدة (29 نوع) ثم الرخويات (19 نوع ، أما الحلقيات قليلة الأشواك والقشريات كل منهما ممثلة بأربعة أنواع ، ما العلقيات والهيدروزوا والبرايوزوا فكل منها ممثل بنوع واحد فقد . وبينما سجل اسكاروس (988 ، 993) 40 نوعاً من الأحياء القاعية فقد تعرف فيشار (995) على 37 نوع ، منها 19 نوعا سبق التعرف عليها بواسطة اسكاروس ولكن لم يسجلها فيشار

الذى أمكنه التعرف على 13 نوعا جديدا لم تسجل من قبل ، وهذا يعزز ما توصل إليه المؤلفون بأنه من المتوقع تسجيل أنواع جديدة من الكائنات بالبحير ، ذلك لأن معظم الدراسات تجــرى – كمــا ســبق أن ذكرنـ – ي مناطق محدد ة ولفترة زمنية محدود .

وتعتبر الحلقيات قليلة الأشواك (oligochaetes) والحشرات من أكثر أحياء القــاع شــيوعا إذ أند ا تمثلان 8.7 % و 1.9 % ، علي الترتيب، من المجموع الكلى للأحياء القاعيه . وبالنسبة للــوزن الـ ي تمثل الرخويات أعلى كتلة ي الجا ين الشر ي (3.3 %) والغر ي (7.7 %) للمجرى الرئيسـ ي للبحير . وقد كان ترتيب الحلقيات قليلة الأشواك ي المقدمة ي المجرى الرئي ي للبحيــر ، وأن أدنـــى كتلة حيوية كانت للهيدروزوا والبرايوزو . كما أن المناطق الشاطئ ة أكثر كثافة وأعلـــى كتلـــة حيويـ ة للأحياء القاعية عنها ي المجرى الرئي ي للبحير . وإن الجانب الشر ي للبحيرة أغنى ي أحياء القــاع من الجانب الغر ي سواء ي عددها أو ي كتلتها الحيوي ، وإن الأخوار سواء مناطقهــا الشــاطئية أو العميق) تكون أغنى ي أحياء القاع من المجرى الرئي ي للبحير . وإن منطقة أمادا (200 كــم جنــوب السد الع ي) ي أغنى منطقة ي أحياء القاع مقارنة ببقية المناطق الجنوبية والشــمالية للبحيــر ، ممــا يستد ي إجراء مزيد من الدراسات التفصيلية على هذه المنطقة وأيضا علـــى المنـــاطق الأخــرى . وإذا أخذنا ي الاعتبار تغير كثافة الأحياء القاعية طبقا لفصول السن ، نجد أن فصل الخريف هــو أفضـــل فصل لانتاج الأحياء القاعية ثم يليه الربيع والصيف ، أما أقلها ي الإنتاج فهو فصل الشتا .

والج ير بالذكر أن هناك بعض الأحيــاء القاعيـــة مـــن القشـــريات مثـــل الكابوريـــا النيليـــة *(Potamonautes niloticus)* التى سبق تسجيلها ي بدء تكوين البحير ، إلا أنها لم تظهر بعــد ذلـــك ولم يسجلها الباحثون .

ونظرا للأهمية البالغة لبحيرة ناصر كمصدر للثروة السمكي ، كما أن إنتاجيتها السم ية مرتفع ، والأسماك المصيدة منها غير ملوثة إذا ما قورنت بالأسماك المصيدة من أى مسطح م ي آخر ي داخل جمهورية مصر العربي ، لذلك فقد خصص المؤلفون خمسة فصول تتناول الثروة السمكية ي :

– التنوع الحيوى وبيولوجية الأسماك . د – طفيليات الأسماك وامراضه .

جـ – . صائد الأسماك – تنمية المصائ .

هـ – الاستزراع السمكي .

ويتناول **الفصل السابع : التنوع الحيوى للأسماك وبيولوجية الأنواع ذات القيمة ا! قتصـــادي** وهو يناقش مدى التغير ي التركيب النو ي للأسماك منذ باكورة تكوين البحيرة وحتى الآن ، فقد تحـــول نهر النيل ي منطقة حيرة ناصر من نهر سريع الجريان إلى بحيرة شبه ساك ة ي الجزء الأكبر منه ، ما عدا المنطقة الجنوبية من البحيرة حوالى 50 كم تقريب) ي نهرية خلال موسم الفيضان ، مما أثـــر على التنوع السم ي ، إذ اختفت معظم أنواع الأسماك النهرية وأصبحت نادرة الوجـــو ، كمـــا ســـادت الأسماك التى أمكنها التأقلم ي البيئة الجديد ، خاصة أسماك البل ي بأنواع .

ي عام 1974 سجل عبد اللطيف 56 نوعا من الأسماك تنتمي إلى 15 فصيلة ، وكانت من بينها أسماك الشال ة والراية وكلب السمك والأنوم ة واللبيس والبي والبياض وغيرها والموجودة بكثافة عالية ي بحيرة النوبة ، أصبحت نادرة الوجود ي بحيرة ناصر . ومن المحتمل أنه في السنوات ذات الفيضان العالي قد تظهر أنواع الأسماك السابقة الذكر بكثرة ي المناطق الشمالية للبحير ، مما يستدعي دراسات مستمرة تفصيلية على أنواع وعشائر الأسماك . أما حاليا فتعتمد مصايد بحيرة ناصر على نوعين أساسيين من البلطي (الجاليلي والنيلي) ويكونا حوالى من 90 إلى 5 % من المصيد الكلي من الأسماك ، كما أن هناك نوعين آخرين من البلطي (الأبيض والأخضر) تتواجد ي البحيرة بكميات قليلة ، وربما يحدث توازن بين هذه الأنواع الأربعة من البلطي ي المستقبل القريب . لذلك يجب إجراء دراسات تفصيلية على هذين النوعين الآخرين من أسماك البلطي ؛ ومدى تأثيرهما في التركيب المحصولي للبحير .

وتمثل الأنواع الأخرى من الأسماك مثل كلب السمك والراية بأنواعها وقشر بياض والبياض والدقماق واللبيس بأنواعه نسبة صغيرة من المصيد الكلي خاصة ي العقدين الأخيرين ، وهذا يدل على مدى أثر تغير النظام البيئي من نهري إلى بحيري على التنوع السمكي ي البحير .

وتناول الفصل السابع معلومات هامة عن بيولوجية الأسماك ذات القيمة الاقتصادية العالية ، ومن ذلك نوعية الغذاء والعادات الغذائية ، النمو ي الطول والوزن ، الخصوبة ، موسم التكاثر وحجم البويضات وأماكن وضع البيض ي الماء أو على القاع).

وتبعا لنوعية الغذاء والعادات الغذائية تم تقسيم أسماك بحيرة ناصر إلى 4 مجاميع :

- أسماك تتغذى على الهائمات والطحالب العالقة مثل أسماك البلطي بأنواعه .
- أسماك تتغذى على الهائمات الحيوانية والحشرات مثل الراية بأنواعها .
- أسماك متنوعة الغذاء مثل الشلبة بأنواعها والأنومة واللبيس والبني وغيرها .
- أسماك لاحمه تتغذى على الأسماك وغيرها من الحيوانات ومنها قشر بياض والبياض والدقماق والقرموط وكلب السمك والتى تكون الأسماك نسبة عالية في غذائها عندما تصل إلى أطوال معينة .

ومن ناحية نمو الأسماك الهامة اقتصاديا نجد أن ي حالة المجموعة العمرية الرابعة يصل وزن البلطي النيلي إلى 2836 جراماً بينما ي حالة البلطي الجاليلي يصل الوزن إلى 344 جراماً في نفس العمر . وبذلك يزيد نمو البلطي النيلي بمقدار أكثر من ضعف وزن الجاليلي .

وبتحليل الدراسات علي معدلات النمو للبلطي بنوعيه منذ عام 1964 وحتى الآن ، وجد أن هناك انخفاضاً ملموساً ي معدلات النمو لكلا نوعي البلطي ي السنوات الأخير . وقد نوقشت أسباب ذلك والتى قد ترجع إلى أثر التخزين لفترات طويلة كما حدث ي بحيرات أخرى ي أفريقيا . لذلك يرى المؤلفون أن تجرى دراسات لاحقة ومفصلة وعلى أعداد كبيرة من نوعي البلطي وأيضا على الأنواع الأخرى من الأسماك ذات القيمة الأقتصادية العالية عن هذه الظاهرة والتى بلا شك ستؤثر مستقبلا على الإنتاج السمكي في بحيرة ناصر .

ومن حيث موسم تكاثر أسماك حيرة ناصر يمكن تقسيمه إلى :

– أسماك ذات موسم تكاثر طويل مع ذروة ـــي التكاثر خلال فص ي الربيع والخريف ، ومن هذه الأسماك البلـ ي بأنواعه والراية وقشر بياض .

– أسماك تتكاثر خلال موسم الصيف مثل الراية نوع الستس باريمو ي ، اللبـــيس الأســو ، الـ ي ، الشلبه والأنو ة بأنواعه .

– أسماك تتكاثر خلال فصل الشتاء مثل اللبيس النـ ي .

وقد أمكن تحديد موسم التكاثر للأسماك بناءً على أطوار النضج ، والمعامل المنـ ي ، وحجم البويضات .

وبينما بعض أنواع الأسماك ذ ي عشوشاً لوضع البيض مثل البلـ ي ، البياض ، والدقماق) نجـــد أنواعاً أخرى تضع بيض طافياً ي الماء قشر بياض) ومن الأسماك ا يهاجر لوضع البـــيض مثـــل أسماك رايه نوع الستس باريموزى *(Alestes baremoze*) ي موسم الفيضان نحو أعالى نهر النيل والحافز على ذلك هو الدفعات الأولى لمياه الفيضان .

وأشارت الدراسة إلى حجم الأنواع المختلفة من الأسماك عند نضجها لأول مرة حيث وجـــد أن أصغرها حجما ينضج عند طول سم نوع الراية ، بينما أكبرها حجماً ضـــج عنـــد طـــول 2 ســـم الأنومـ). كما شمل هذا الفصل دراسة عن خصوبة بعض أسماك بحيرة ناصر ، بما فيهـــا الخصـــوبة المطلقة والنسبية وعلاقة كل منها بالطول والعمر .

وقد يكون التنافس بين الأسماك على مناطق التكاثر أحد أسباب سيادة البلـ ي الجـــا ي علـــى البلـ ي الـ ي ي بحيرة ناصر خلال العقدين الأخيرين ، إذ يرى المؤلفون أن كلا نو ي البلطـ ي يبنـ ي عشـ شاً ي نفس المناطق الشاطئية ، كما أن لهما نفس السلوك التكاثري ، فبينما يتكاثر البلـ ي الجـــا ي دوال العا ، يتكاثر البلـ ي الـ ي مرتان أو ثلاثة على الأكثر ي العام بـــذروه فـ ي مـــارس – مـــايو ، أغسطس – سبتمبر إضافة إلى ذلك فإن ي البلـ ي الجا ي كلا الجنسان ذكور وإناث) يقـــوم برعايـــة الصغار أما ي حالة البلـ ي الـ ي فيقتصر ذلك على الإناث فقط . وعموما يجب استكمال الدراسة فـ ي هذا الصدد .

ولما كان معدل إصابة أسماك بحيرة ناصر بالطفيليات عالياً وعلى وجـــه الخصـــوص نـــوعي البلطي النيلى والجاليلي) حيث وجدت الديدان الخيطية (Nematoda) داخل الأمعاء وعلـــى الخياشـــيم وفي القلب، مما سبب انزعاجاً للمستهلكين، واستدعى صدور تعليمات بنزع الـــرأس والأحشـــاء قبـــل تسويق الأسماك، لذلك خصص **الباب الثامن** لاستعراض الدراسات على **الطفيليات التى تصيب أســـماك البحير** ، نظراً لأهمية دراسة التطفل واثره على معدلات النمو والتكاثر والمناعة، والذى ينعكس بالتالى على الإنتاج السمكي الكلي . ويرى المؤلفون ضرورة استكمال لك الدراسات ومتابعتها للتعـــرف علـــى دورة حياة الطفيليات، واثرها على الأسماك ومدى نقلها للإنسان والأمراض التى تسببها لـ .

ففي إحدى الدراسات المبكرة عام 974 /976) وجد أن 2.4 % من 19 نوعاً من أسماك البحيرة مصابة بديدان التريماتودا، السستودا، أكانثوسيفلا والخيطـ . وفي دراسة لاحقة عام 983)

وجد أن 5.8 % من 30 نوعاً من أسماك بحيرة ناصر مصابة بنفس المجموعات الأربعة من الطفيليات سابقة الذكر، وأحياناً يصاب النوع الواحد من الأسماك بأكثر من نوع من الطفيليات .

وقد سجلت ديدان التريماتودا في أسماك البياض والدقماق واللبس والقراميط والقرقور والبني والفهقة، كما وجد نوع واحد من الميتاسركاريا في نوعي البلطي النيلي والجاليلي). أما طفيليات السستودا فوُجدت في أسماك البني والشال والقراميط، كما أصابت الديدان الخيطية نيماتود) أسماك البياض والشال وقشر بياض وكلب السمك والشلبة وبلطى النيلي والجاليلي . أما الأكانثوسيفلا فوُجدت في القراميط، البياض، الدقماق، قشر بياض ساموس) والبلطي بنوعيه والفهقة، ومن حيث الإصابة بالأسبيدوكوتيلا فقد كانت نادرة الوجود وسُجلت في الشال والدقماق وقشر بياض ونوعي البلطي .

وسجل على الأقل ما يزيد عن 40 نوعاً من الديدان المتطفلة على أسماك بحيرة ناصر الشائعة، كما تمثل الإصابة الكلية بجنس واحد من التريماتودا ضعف مقدار الإصابة بجنسين .

ومن أنواع الطفيليات الشائعة في أسماك بحيرة ناصر نوع يسمى الكونتراسيكم في طوره اليرقي الذى عرفه بعض البحاث تعريفاً خطأ تحت اسم لامبلسيكم، ويوجد في التجويفين البطني والتنفسي لأسماك البلطي الجاليلي وقشر بياض والبني والقرموط والشال والأنومة، وللآن لم يسجل أي إصابة للانسان في مصر بطفيلي الكونتراسيكم - وان كانت معروفة في اليابان . ويجب أن تتخذ الاحتياطات اللازمة لمنع نقل الطفيلي للانسان ، وذلك عن طريق نزع أحشاء الأسماك والرأس بعد صيدها مباشرة، كما يحب طبخها أو تمليحها جيد . وقد وجد أن تجميد الأسماك لمدة 3 أيام فى درجة - 20 م أو تسخينها لدرجات أعلى من 50 م لمدة عشر ثوان كافية لقتل الطفيلي . ومن المعلوم أن التدخين أو التمليح الخفيف لا يؤثر مطلقاً على يرقات الكونتراسيك . والجدير بالذكر أن الكونتراسيكم الذي يصيب الأسماك في بحيرة ناصر هو الطور اليرقي الذي يتم دورة حياته في الطيور آكلة الأسماك . وتوضح الموسوعة الحالية أنه يوجد 19 نوعاً من الطيور آكلة الأسماك في بحيرة ناصر . وان أعداد الطيور قد زادت بعد تكوين البحيرة مما يفسر الاصابات العالية لأسماك البحيرة بالطفيليات التى تنقلها الطيور . وفي عام 1961 سُجل 63 نوعاً من الكونتراسيكم في انحاء العالم والتي يعيش طورها اليافع في قانصة الطيور . ولذلك فان بحوثاً عن دورة حياة هذا الطفيلي وأنواعه في البحيرة من لدراسات الهامة التى يجب استكمالها . كما أن دراسات أكثر شمولية عن طفيليات الأسماك وأنواعها وكثافتها ودورة حياتها في بحيرة ناصر أمر ضروري لتكملة معرفتنا عن هذه الطفيليات، وهل هي تسبب أمراضاً للانسان ومدى تأثيرها على الثروة السمكية؟

ويتناول **الفصل التاسع مصا د الأسماك بالبحيرة** وتتبع تطورها منذ تكوينه . ففي الفترة الأولى من تكوين بحيرة ناصر (1966 /1975) كانت مصائد الأسماك متعددة في أنواعها، إذ تم تسجيل 56 نوعاً تنتمى إلى 15 فصيلة، وكان من أهم أنواع أسماك المياه المفتوحة والشائعة هي الراية بأنواعها، كلب السمك و لشلبة النيلي والبني واللبيس وغيره . أما أنواع أسماك المنطقة الشاطئية فهي البلطي النيلي والجاليلي، السردينة، كلب السمك وقشر بياض .

لقد اعتاد الصيادون تسليم إنتاجهم من الأسماك سابقة الذكر إما طازجاً أو مملحاً، وتشمل الأسماك الطازجة كلا من : البلطي بنوعيه، قشر بياض، البياض بنوعيه، اللبيس والقرقور . أما الأسماك المملحة فتشمل كلب السمك، الراية، السردينة والشلبة . وفي الفترة الأولى من تكوين البحيرة (966. /968) كانت الأسماك المملحة تمثل 1.8 % من جملة الإنتاج السمكي السنوي ثم انخفضت إلى 2.7 % في الفترة من 1969 إلى 978 ، وأصبحت تمثل 0.3 % فقط في الفترة من 1979 إلى 1996 من جملة الإنتاج السمكي .

وفي الوقت الحالى فان مصائد الأسماك يسودها البلطي الجاليلي والنيلي اذ يتراوح انتاجها مــن 90 إلى 5 % من الانتاجية الكلية . أما بقية الأنواع الأخرى فقد تــدهورت إنتاجيتهــا إلــى مســتويات محسوسة بل وإنها في طريقها للاختفاء . لقد حدثت تغيرات جذرية في بحيرة ناصر سواء تغيرات بيئية أو فيما يختص بمصائد أسماك البحيرة أو من حيث التنوع السمكي ذلك منذ باكورة تكوين بحيرة ناصر وحتى الآن .

وقد لوحظ أن المصيد الكلي من الأسماك خلال شهور فصل الربيع كانت ضعف المصيد فــي أشهر الصيف، وعلى وجه الخصوص فى المنطقة الجنوبية من البحيرة بالقرب من العلاقي وكورســكو وتوشكي والتى سجل فيها أعلى قيم لكل من كلوروفيل " والعوالق الحيوانية .. وتوحي هــذه الظــاهرة بإمكانية اقامة مصائد نشطة في المنطقة الجنوبية، وخاصة أن انتاجية تلك منطقة تعادل مرة ونصــف المصيد من الجزء الشمالي .

وقد سجلت الدراسة الحالية انخفاضاً في الانتاجية الكلية للبحيرة منذ عــام 1983 وقــد عــزى الباحث أحمد (994.) التدهور في الإنتاج السمكى إلى أســباب إداريــة وتســويقية فــي المقــام الأول بالإضافة إلى تذبذب مناسيب المياه، في حين يرى الباحث مكاوى (998.) أن هذه الأسباب تــأتى بعــد مناقشة المصيد على ضوء الظروف البيئية وخصائص البحيرة المتغيرة في المكان والزمان، خاصة وأن هناك تدهوراً في جميع أنواع الأسماك ما عدا أنواع البلطي التى تظهر ذبذبات . أمــا بــالارين (986.) فقد أشار إلى تدهور مخزون البلطي النيلي الذي يصل إلى أطوال في النمو أكبر من أطــول البلطــي الجاليلي) في الوقت الذى يتزايد فيه مخزون الجاليلي من حيث العدد، هذا الأمر يعكس تغيرات كبيــرة حدثت في بحيرة ناصر وهي المسئولة عن ذلك .

ما هى أسباب التدهور في إنتاج الأسماك في بحيرة ناصر ؟ هل هــو تجــاه البحيــرة نحــو التخصيب (eutrophication) ؟ لقد أدخل نيومان (Naumann 919.) تعبيــري قليــل التخصــيب (oligotrophic) ومخصب (eutrophic) لتصنيف البحيرات، فالبحيرات قليلة التخصــيب ذات مــاء صاف بينما تكون البحيرات المخصبة ذات ماء عكر بسبب وجود الطحالب . وعرّف ماســون (Mason 991.) التخصيب بأنه ثــراء المــــاء بمغــذيات النبـــات غيــر العضــــوية (inorganic plant nutrients) وتلك المغذيات تشمل عادة النيتروجين والفوسفور، ينتج عنها زيادة فــي الإنتــاج الأولــي (primary production) ، كما وضــع بريماه (Braimah 995.) الخزانــات الكبيرة في واحد مــن خمسة أقسام تصف حالة الخزان الغذائية باستخدام مســتويات الإنتــاج الســمكي (fish production levels) كمقياس يكون فيها في البحيرات المخصبة إنتاج الأسماك أكثر من 60 كجـ هكتــار عــام .

وباستعراض الدراسات على إنتاجية بحيرة ناصر , نلاحظ انها قد مرت بثلاثة مراحل مـــن التخصـــيب أذ ر صر : 3 , ا).

وقد اوضحت الدراسة الحالية باستعراض نتائج البحوث منذ تكوين بحيـــرة ناصـــر أن هنـــاك تخصيباً تدريجياً لبحيرة ناصر نتيجة للترسيب المستمر للمواد العضوية التى تحملها مياه الفيضان الغنية بالأملاح المغذية على قاع البحير .

وتتراوح الإنتاجية الأولية لبحيرة ناصر من 4.32 إلى 128.15 ملجم ك م/ ساعة عبد المنعم 995 ، وتعتبر بحيرة ناصر أكثر خصوبة من البحيرات الصناعية الثلاث في أفريقيا بحيرات فولتـــا، كانيجي وكاريبـ ، إذ يتراوح تركيز الفوسفات، نيتروجيـ - النترات (NO_3-N) ، والســليكون بــين 0.02 إلى 0.52 ؛ صفر إلى 3.0 ؛ 10 إلى 35 ملجـ لتر على التوالي .

وللتخصيب آثار أشار إليها ماسون (Mason 991 ، ويمكن الإشارة بشكل عام إلى التغيرات الملحوظة التي يحدثها التخصيب في كائنات المياه العذبة، فمثلاً البحـــيرات منخفضة المغـــذيات قليلـــة التخصيبـ) تكـــون غنيـــة بالديزميدات desmids بينمـــا ســـود الطحالـــب الخضـــراء المزرقـــة (Cyanophyceae - Cyanobacteria) في البحيرات ذات التركيزات العالية من المغذيات .

لقد لخص هارتمان (Hartmann 977) التغيرات العامة في أنواع الأســماك تحــت تــأثير التخصيب معتمداً في ذلك على معلومات من 51 بحيرة أوروبية، وأوضح أنه في مراحل المتوســطة للتخصيب تزداد بحدة أسماك الشبوطيات (cyprinids ، بينما تتدهور بشدة هذه الأســماك فــي الميــاه شديدة التخصيب (heavily eutrophic water . مما سبق يمكن القول بأن بعــض الأســماك يعتمــد بشكل كبير على ظروف التخصيب أكثر من اعتماد البعض الآخر عليها، وتتوقف علاقة الســيادة بــين الأنواع فى أى نظام بيئي على تحسن أو تدهور التخصيبـ .

وعموماً تؤدى زيادة التخصيب بالمغذيات إلى أخطار وتغيرات في مجتمع الأسماك والتركيــب النوعي له، هذا التغير يرجع إلى انتزاع الأكسجين (deoxygenation) مـــن المناطق القريبة من القاع (hypolimentic water ، ويمكن أن يظهر نقص الأكسجين في مـــياه التخصـــيب عنـــدما تمـــوت الطحالب والنباتات الكبيرة وتتحلل، مما يؤثر على عدد وأنواع الأسماك الموجودة في البحير . وقد سبق وذكر ص1) أن ظاهرة الازدهار الطحلبي (algal blooms) والناتجـــه عـــن زيـــادة التخصـــيب أصبحت تحدث في البحير ة طوال العام وعلى امتدادها من الجنوب للشمال .

هل التدهور فى الإنتاج السمكي بسبب تهريب الأسماك؟ الجدير بالذكر أن الإنتاج الكلـــي مـــن أسماك بحيرة ناصر والذي تضمنته الدراسة الحالي) هو ما يُسلمّ فعلا لميناء السد العالي والذى تصدره نشرة قسم الإحصاء بهيئة تنمية حيرة السد العالي، وهو لا يمثل الإنتاجية الفعلية حيث أن نسبة كبيـــرة من الأسماك تُهرب بطرق غير مشروعة لبيعها بأسعار مرتفعة، ويرى المؤلفـــون أن تتـــرك إنتاجيـــة البحير - مثل باقى بحيرات مصر - للعرض والطلب حتى يمكن تسجيل الإنتاجية الفعلي .

هل التدهور في الإنتاج السـ كى بسبب مشاكل بيولوجيـ . لقد وجد مكاوى (998) ارتباطا ما بين نوع الأسماك ذات المصيد الأعلى البلطي بنوعيـ) والأنواع الأخرى منه , وأضـــاف الباحـــث أن

تدهور إنتاج الأسماك يتعلق بمشاكل بيولوجية في المقام الأول، فالتدهور في الأسماك القطيه القــراميط والقراقير الخ) في بحيرة ناصر على سبيل المثال، لافت للنظر، خاصة وأن معظم هذه الأسماك قاعيــه، والزيادات في عشائر الأنواع القاعية كما ذكر ماشينا (Machena 995) تمثل اتجاهــا شــائعا فــي التكوين البيولوجي (biological development) للخزانات وهو ما لا يحــدث فــي بحيــرة ناصــر ويحتاج لبحث عن السبب .

العوامل المؤثرة في المصيد من الأسماك

1 – هناك عوامل غير مباشرة تؤثر على جودة المياه اللازمة لحياة الأسماك ونموها الطبيعي ومن هذه العوامل : المعلقات الصلبة الدقيقة، الأس الايدروجيني، درجات الحرارة، الأكسجين الذائب، عسر الماء، الأمونيا، سرعة المياه، عمر الأسماك، حجم الأسماك وسلوك الأسماك وغيرها من العوامل . وتعمل جميع العوامل السابقة كوحدة واحدة فلا يمكن الاشارة إلى أحد هذه المؤثرات دون الأخذ فى الاعتبار العوامل الأخرى، وأن مجرد حدوث تذبذبات يومية أو موسمية أو مكانية قد يكون سبباً كافياً لاحداث تأثير ضار على الأسماك خاصة من ناحيتي التكاثر والنمو، والأمر يستدعي النظرة الشاملة المترابطة لكل عناصر النظام البيئي، ويرى المؤلفون أنه قد حان الوقت لاجراء الدراسات المتكاملة للتعرف على العوامل التى تؤثر في الثروة السمكية ككل .

2 – أثر مناسيب المياه على المصيد الكلي والمصيد لكل وحدة جهد (CPUE) .

من الظواهر الهامة التى سجلتها الدراسة الحالية وجود علاقة بــين المصــيد الســنوي الكلــي ومناسيب المياه في بحيرة ناصر، والتى تتذبذب بشكل ملحوظ من عام لآخر . ففــي عــام 1966 بلــغ المصيد 751 طناً، زادت عام 1976 إلى حوالى 16 ألف طن نتيجة لزيادة منسوب المياه وعدد قوارب الصيد . وعند ثبات منسوب المياه عند ارتفاع 174 متر فوق سطح البحر، وكــان جهــد الصــيد ثابتــاً (1600 قارب صيد ، بلغ الإنتاج السمكي ذروته عام 1981 حوالي 34 ألف طن . ومن عام 1983 إلى 1988 وهى فترة الجفاف – حيث انخفض منسوب المياه من 171.1 إلــى 150.6 متراً فوق ســطح البحر – انخفضت الإنتاجية من 31 ألف طن إلى 16 ألف طن . وفي الفترة من 1989 إلى 1992 كان الحد الأدنى لمنسوب المياه 164.3 إلى 163.8 متراً وبلغت الإنتاجية 15.6 و 26.2 ألف طــن علــي التوالي ثم حدث انخفاض حاد فى الإنتاجية عام 1993 وكانت 17.9 ألف طن تبعها زيادة عــام 1994 إلى 22 ألف طن تم انخفاض فى عام 1997 20.6 ألف طن , وعام 1998 19.2 الف طن .

لقد وجد وليمز (Williams 972) ارتباطاً موجبا بين منسوب المياه والمصيد لكل وحدة جهد في بحيرة ميراو (Mweru) بزامبيا وأرجع هذا الارتباط إلى تأثير التغيرات في منســـوب الميـــاه علــى مناطق تــوالد بعض أنواع الأســماك مثل بلطي ماكروشير *Tilapia macrochir)* . وأفــاد بهكاسوان (Bhukaswan 976) بأن زيادة المصيد يمكن أن تكون عكسية مع زيادة مناســيب الميــاه ولا يرتبط ذلك بنمو البلانكتون، ويبين هذه العلاقة في خزان أوبلراتانا (Ubolratana) بتايلانــ . كمــا أشار بريماه (Braimah 995) إلى العلاقة العكسية بين المصيد ومناسيب المياه في بحيرة فولتا بغانا .

– أثر مناسيب المياه والجهد على المصيد الكلي من الأسماك .

سجل مكاوي (998) طبيعة العلاقة بين المصيد الكلي من أسماك بحيرة ناصر ومناسيب المياه في الأعوام الستة التي تسبق هذا المصيد (WL1 to WL6 ، وجهد الصيد ممثلاً بعدد المراكب أو عدد الصيادين في العام ، كذلك الأمر بالنسبة للمصيد من كل نوع من الأسماك على حدة، استنتج مكاوي (998) النتائج التالي :

يرتبط إنتاج البلطي ارتباطاً ذا دلالة مع مناسيب لمياه من WL2 قبل المصيد بعامين) إلى WL6 قبل المصيد بست أعوام) فقط، ولا يوجد أرتباط مع جهد الصيد؛ ويرتبط إنتاج كلب السمك دلالياً فقط مع WL1 و WL2 قبل المصيد بعام أو عامين) ومع عدد الصيادين . و يرتبط انتاج قشر بياض دلالياً مع WL5 قبل المصيد بخمس أعوام د). لا يرتبط انتاج اللبيس دلالياً مع مناسيب المياه ولكنه يرتبط مع عدد المراكب . يرتبط إنتاج البياض دلالياً مع مناسيب المياه من WL4 إلى WL6 المصيد قبل 4 إلى 6 أعوام فقط ، ولا يوجد ارتباط ذو دلالة بين إنتاج القراميط ومناسيب المياه وجهد الصيد . يرتبط المصيد كلي من الأسماك فقط مع مناسيب المياه من WL2 إلى WL6 المصيد قبل عامين إلى ست أعوام) وهو بذلك يعكس الصورة في حالة البلطي .

وطرح مكاوي (998) الانحدار الخطى المتعدد العلاقات (Multiple linear regression) باعتبار أن مناسيب المياه في الأعوام الست التى تسبق المصيد) والجهد ممثلاً بعدد المراكب / عام، وعدد الصيادين / عام) متغيرات مستقلة وأن المصيد متغير تابع . ولعل الصورة التى طرحها الانحدار الخطي المتعدد العلاقات تكون أفضل للتنبوء بكميات المصيد من الأسماك آخذين في الاعتبار كلاً من مناسيب المياه والجهد . وهذا الطرح أفضل من إيجاد علاقة مستقلة بين منسوب المياه والمصيد لكل وحدة جهد حيث تكون العلاقات متعددة والاستنتاجات متعددة أيضاً .

وعموماً تشير الدراسات إلى أنه ليس كل أنواع الأسماك تتأثر بمناسيب المياه أو الجهد، وإذا تأثر البعض فإنه يتأثر بمناسيب المياه في سنوات معينة، والبلطي أكثر هذه الأنواع تأثراً بمناسيب المياه وهو ما ينعكس على المصيد الكلي في بحيرة ناصر .

ونظرا لأهمية بحيرة ناصر كمصدر رئيسي للثروة السمكية بمصر إذ أنها تساهم بحوالي 0 – 5 % من الإنتاج الكلي من الأسماك سنوياً، لذلك تناول الفصل التاسع دراسة تفصيلية عن مصائد البحيرة وخاصة أن تقييم تلك المصائد أمر ضروري لتنمية وإدارة المصادر التى تعتمد عليها المصائد، ويتطلب ذلك تقييماً أولياً لمستوى استغلال المصائد مقارنة بثروتها السمكية الكامنة أي المخزون السمكي، إضافة إلى ذلك فان تفاصيل المعوقات الايكولوجية والبيولوجية – والتى سبق الإشارة إليها – لازمة للمتابعة .

لقد حدثت تغيرات كبيرة بيئية – تنوع سمكي – مصائد الأسماك – كما سبق ذكرها – منذ بدء تكوين بحيرة ناصر حتى الآن، ونظراً لأهمية دراسة منسوب المياه بالبحيرة للمصائد، لذلك فالتعرف على التغيرات السنوية في مساحة البحيرة وحجم المياه بها وعلى وجه الخصوص الأخوار، أمر ضروري لتقييم المخزون السمكي والتنمية الشاملة، كما أن طول الشاطيء وميله وطبيعته من الأمور الهامة لنمو الطحالب العالقة، وكذلك الأحياء الشاطئية والتي تكون الغذاء الرئيسي لأسماك

البلطي المحصول الرئيسي للأسماك من البد ر). وأيضاً تعتبر المنطقة الشاطئية من أفضـل وأنسـب المناطق لتوالد البلطي .

وباستعراض دراسات مصائد بحيرة ناصر، لوحظ أنه لا توجد معلومات كافية وصحيحة عـن كميات الأسماك الموجودة في المياه الشاطئية وبعد الشاطئية وحتى المياه المفتوح . وحـديثاً أجـرى مكاوي دراسات ذ صيلية لتقييم كميات الأسماك ببحيرة ناصر خاصة أسماك البلطي وكذلك عـن تـأثير التخزين على أسماك البحيرة كما سبق ذكر .

هذا وقد أمكن إجراء عدة تقديرات خاصة بالقدرة الإنتاجيـة الكامنـة السـنوية (Potential annual yield) من الأسماك باستخدام المعامل المورفوايـدافيك (Morphoedaphic Index MEI . والجدير بالذكر أن النماذج الخاصة بمعامل المورفوايدافيك MEI تعكس فقط وجهاً واحداً من العوامـل الايكولوجية والبيئية والمصايد، كما تتوقف دقة النتائج على مدى التحديث المستمر للمعلومـات، ولهـذا السبب يبحث مديرو المصايد عن نماذج أخرى يؤدي استخ امها إلى الحصول على تنبؤات أكثـر دقـة تمكنهم من رسم الخطط المستقبلية لادارة المصاي .

وباستخدام منسـوب المياه فـي البحيرة وطـول شاطئها أمكـن تقديـم نمـوذج للانحـدار (regression model) يفيد في التنبؤ عن كمية الأسماك من البلطي التى يمكن صيدها سنوياً من بحيرة ناصر . كما أمكن تحديد كمية الأسماك المصيدة سنوياً من بحيرة ناصر عن طريق اسـتخدام الإنتاجيـة الأولية للهائمات النباتية فيتوبلانكتوز). وفي الدراسة الحالية تم تقديم طرق مختلفة تستخدم فـي تقـدير الإنتاجية السنوية القصوى التي يمكن الحصول عليها من أسماك البحيرة والتـى عـرف بالإنتاجيـة المستدامة القصـوى (maxmimum sustainable yeield - MSY . وباسـتخدام معيـار كاديمـا (Cadima′s estimator) تم تقدير قيم أقصى إنتاجية سنوية مستدامه لكل من أسماك البلطـي النيلـي، والجاليلي وقشر بياض، خلال الفترة من 1966 إلى 992 ، إلا أن هذه القيم كانت مرتفعة عن الحقيقة، حيث أن النتائج التى تم الحصول عليها تعتمد فقط على المصيد السنوى من الأسماك وجملـة الوفيـات (total mortality) لغرض الحصول على النتائج، ولم تستخدم بيانات كاملة على المدى الطويل .

وباستخدام نماذج مختلفة لتقدير أقصى إنتاجية سنوية مستدامة (MSY) أ كن الحصول علـى إنتاجية تتراوح من حوالي 50 إلى 62 ألف طن، وفيما يلي تلك التقديرات :

– تم استخدام بيانات عن الجهد المستخدم في الحصول على المصيد من الأسماك في الأخوار خلال الأعوام 1988 – 1994 فى نموذج شيفر (Schaefer′s Model ، وتم تقـدير أعلـى إنتاجيـة شهرية لكل منطقة على حدة، وبالتالى وجدت أقصى إنتاجية مستدامة تعادل 59742.24 طن عام، كمـا استخدمت بيانات عن جهد المصيد الكلي من الأسماك خـلال الفتـرة 1973 – 1992 فـي نمـوذج هيبربوليك (Hyperbolic Model) وتم حساب أقصى إنتاجية مستدامة بـ 55616.69 طن / عام، كما تم استخدام لنموذج الكلي لشيفر (Holistic Model of Schaefer) في بيانات عن المصيد لكل وحدة جهد (CPUE) عن الفترة 973 –1992 لأسماك البلطى بنوعيه النيلي والجـاليلي) ، وعـن الفتـرة 966 –1992 للأنواع الأخرى من الأسماك . وتم حساب أقصى إنتاجية مستدامة بـ 61644.78 طن / عام من كل أنواع الأسماك وتمثل أسماك البلطي بنوعية حوالى 0.74 % منها، ومن الواضح أن أعلى

إنتاجية مستدامة للأنواع الأخرى من الأسماك كانت منخفضة وتعكس الظروف القاسية التى تحــد مــن انتاجيتهم . ومع الأخذ في الاعتبار مساحة البحيرة حيث أنها تؤثر على مناطق التكاثر . تم تطبيق ذ وذج شيفر المعدل والمقترح على بيانات عن جهد المصيد الكلي (otal catch effort) وتم حساب أقصــى إنتاجية مستدامة لأسماك البحيرة عند أقصى مساحة تعــادل 250000 فــدان أى تعــادل 505868 هكتار) بــ 57492.27 طن عام وذلك باستخدام 1313 قارب صيد، كما أمكن حساب أقصى إنتاجيــة مستدامة لأسماك البلطى بنوعيه 53755.27 طن عا .

– وباستخدام منحنى جراهام (Graham curve الذى يوضح العلاقة بين الإنتاج الزائد مــن الأسماك والكتلة الحيوية لها في بيانات عن جهد المصيد من أسماك البلطي النيلي والجاليلي، تم حساب أقصى إنتاجية مستدامة (MSY) لا لطي بنوعيه بـــ 54107 طن عام وهى تماثل تقريباً تلــك المقــدرة باستخدام نموذج شيفر .

- وباستخدام العلاقة بين الإنتاج الزائد من الأسماك الكتلة الحيوية لها وبين الكتلة الحيوية تم حساب أقصى إنتاجية مستدامة للبلطي النيلي بـــ 26863.28 طن عام بينما تلك للبلطي الج ليلي قدرت بـــ 27243.79 طن عا .

– وباستخــدام النمــوذج العــام لانتــاج المخزون السمكي فوكس 975) (Generalized Stock Production Model) طبقاً للبيانات عن جهد المصيد من أسماك البلطي النيلي والجاليلــي خــلال الفتــرة مــن 1966 إلــى 992 ، وطبقــا للثــــلاث نمــــاذ- : Gompertz, Logistic, Asymptotic تم حساب أقصى إنتاجية مستدامة للبلطي النيلي فكانت 25336.9 طن عــام؛ 15614.1 طن عام؛ 15347.5 طن عام على التوالي، وأيضاً للبلطي الجاليلي كانت تعادل 32970.00 طن عــام، 16542.7 طن عام، 13657.7 طن عام على التوالي . ومما يلاحظ أنه فيما عدا التقدير الذى تم حسابه باستخدام نموذج Asymptotic ، فان التقديرات الأخرى لأقصى إنتاجيــة مســتدامة بالمقارنــة مــع التقديرات السابق ذكرها، أظهرت تغيرات ملحوظة وأعطت أرقاماً منخفضـ . وخلال الفترة مــن 1991 إلى 1992 قدرت أقصى إنتاجية مستدامة لأسماك بحيرة اصر بحوالي 62360.32 طنــ عــام طبقــاً لنموذج Asymptotic مع الأخذ فى الاعتبار أن متوسط النسبة المئوية لأسماك البلطي بنوعيه حــوالى 0.5 % ذلك .

– هذا وقد تم تقدير أقصى إنتاجية مستدامة، والقيمة المالية للإنتاج والكتلة الحيويــة لأســماك البلطي النيلي والجاليلي، باست دام نموذج تومسوز – بــل (Thompson & Bell Model) والــذي يعتمد على بيانات عن عمر الأسماك . فكانت أقصى إنتاجية مستدامة سنوية لكل مــن البلطــي النيلــي والجاليلي تقدر بـــ 30127.64 طن عام، 17692.34 طن عام على التوالي .

ومن المعلوم أن البلطي بنوعيه يتغذى على البكتريا، الهائمات النباتية، الروتيفــرا، مجدافيــة الأقدام والأوستراكودا، وبمعنى آخر أن البلطي بنوعيه يتغذى على أكثر مــن مســتوى غــذائي، وإن النظام البيئي لبحيرة ناصر مناسب تماماً لأنواع الأسماك التى تظهر مرونة في تغذيتها، والتى قد تتعدى حدود المستويات المختلفة من السلسلة الغذائي .

ورغم كثرة العوامل البيولوجية التى يمكنها التأثير على نجاح أنواع الأسـماك – أى التوزيـع والوفر، – إلا أن دراسة التكيفات التكاثرية المختلفة (reproductive adaptations) تعد ذات الأهمية الأولى في هذا المضمار، ومن هنا تأتي أهمية التركيز على بيولوجية لتكـاثر لأنواع الأسـماك فـي بحيرة نـاصر، خصوصاً أن بعض هذه الأنواع مثل اللبيس *Labeo* spp. والبني *Barbus* sp. تحتاج إلى ماء متدفق (flowing water) من أجل تكاثر ناجح، مع الأخذ في الاعتبار التباين في احتياجـات التكاثر . ولابد من تحديد دورة وجهد التكاثر، وزمن ومكان وضع البيض لكل نوع من أنواع الأسـماك ذات المصيد المتدهور، وذلك في سنوات متعاقبة كوجه آخر لتقرير طرق العلاج .

كما أن دراسة العلاقة بين الأسماك والهائمات الحيوانية تعد من الموضوعات الهامـة والتـى تساعد في إتمام عملية إدخال أنواع جديدة من الأسماك أو من اللافقاريات ، لذلك ينبغى دراسة معنويـة لافتراس الأسماك للهائمات الحيوانية . ولقد وجد ارتباط منطقي بين لون وسلوك وحجم كائنات الهائمات الحيوانية ووجود الأسماك التى تتغذى عليه . وقد لوحظ أن الافتراس عامل محدد ومتحكم في وجود أو غياب أنواع معينة من القشريات . هذا الوضع يحتم على دارسي الهائمات الحيوانية أن يربط نتائجه مـع توزيع الأسماك وعددها وحجم المصيد منها حتى تأتي الدراسة ذات معنى وفائد .

ويشير المؤلفون إلى أنه في السنوات الأخيرة انتشرت في بحيرة ناصر أسماك البلطى الأخضر (*Tilapia zillii*) أكل النباتات، وهو يلعب دوراً هاماً في بيولوجية البحيرة، إذ أنه بواسـطته تصـبح المغذيات (nutrients) متاحة للهائمات، وأيضاً تصبح الفضلات الغذائية متاحـة للأسـماك الأخـرى، ويرى المؤلفون ضرورة القيام في المستقبل القريب بإجراء دراسات تفصيليـة على بيولوجية البلطـي الأخضر وأثره على النظام البيئي في بحيرة ناصر، كما يجب دراسة التفـاعلات التـى تحـدث بـين مستويات التغذية المختلفة وأيضاً تحديد الاحتياجات الغذائية لأنواع الأسماك المختلفة في البحير .

وقد قام مكاوى (998) بتقدير كمية الغذاء الكلي السنوى طن) واللازم للحصول على أقصى إنتاجية مستدامة سنوية من أسماك البلطي النيلي أى حوالى 30 ألف طن) وذلك باستخدام معيار كـادي . Caddy's estimator)

ويتناول **الفصل العاشر** دراسة عن **تنمية مصايد الأسماك** والعوامل المؤثرة فيها، مع الإشـارة إلى الصفات الهامة والتى تميز بحيرة ناصر وهو طول الشاطىء، وأيضاً وجود عدد كبيـر (35) مـن الأخوار طولها اخوار العلاقى وكلابشة وتوشكى . وتعتبر الأخوار – كما سبق ذكـر، – مـن أغنـى مناطق البحيرة في كل من الهائمات النباتية والحيوانية، كما أنها أفضل الأماكن لتوالد أسـماك البلطـي بنوعيه النيلي والجاليلي) حيث أن معظم الشواطيء رملية وذات ميل تدريجى مما يجعلها مناسبة تماماً لبناء أعشاش البلطي، أما بخصوص مناطق البحيرة البعيدة عن الشاطىء والمفتوحة فهـي فقيـرة فـي الإنتاج السمكي إلا أنها غنياً – إلى حد ما – بالهائمات النباتية والحيوانية .

ومن مزايا تخزين المياه في البحيرات الصناعية مثل بحيرة ناصر هو تراكم الأملاح المغذيـة بكميات كبيرة مما يؤدي إلى زيادة الإنتاجية الأولية وبالتالي زيادة في الثروة السمكية . وقد اتخذ بعـض العلماء من قياسات عمق البحيرة، ومتوسط كمية الأملاح المغذية المذابة في المـاء، والقاعديـة الكليـة

الكربونات والبيكربونات) ودرجة التوصيل الكهربي عوامل استخدمت في التنبوء بالانتاج السمكي الكلي من خلال معامل مورفواديفيك (Morphoedaphic Index - MEI) .

وعند استعراض إنتاجية بحيرة ناصر منذ تكوينها وحتى الآن نجد أنها مرت بثلاث مراحل ص : 3,ا). ويلاحظ أن إنتاجية البحيرة فى الفترة الثالثة (1978 – 996) من أعلى المعدلات إذا قورنت بانتاجية البحيرات الأفريقية الصناعية الأخرى فولتا وكاريبا وكاينجي ، حيث تراوحت من 53.26 – 116.99 كجم هكتار العام .

وباستخدام النموذج الرياضى لتحديد مسار الإنتاج الكلي من أسماك بحيرة ناصر، وجد بازيجوس (Bazigos 972) أن هناك علاقة قوية تربط بين ثلاث متغيرات وهي : المصيد الكلي التجاري، عدد مراكب الصيد، المساحة الكلية للبحير . ووجد الباحث أن العامل المحدد في التغيرات السنوية للمصيد الكلي التجاري هو مساحة البحيرة إذ تزيد بما يعادل 1.33 مرة أكثر من المتغير عدد مراكب الصيد .

وأشارت الدراسة إلى تطور عدد مراكب الصيد وأعداد الصيادين منذ تكوين البحيرة، ومعوقات التنمية للبحيرة وكيفية التغلب على ذلك من خلال إدارة تعتمد على الدراسات البيئية التى تؤثر في ديناميكية عشائر الأسماك . لذلك يجب المتابعة والرصد المستمر للتغيرات البيئية والبيولوجية للبحير . إضافة إلى ذلك فان دراسات تقييم المخزون السمكي ينبغي أن تعتمد على معلومات فعلية وصحيحة ومتكاملة منها : عدد ومواقع مخيمات الصيد، عدد مراكب الصيد والصيادين، متوسط عدد أيام الصيد لكل مركب، متوسط المصيد من الأسماك في كل مرة، حجم الأسماك المصيدة طبقاً للأنواع والشهور ومناطق الصيد ... لخ .

كما توصي الدراسة باستخدام علامات (tags) فى ترقيم الأسماك لتتبع تحركاتها، وكذلك استخدام ماسح الصدى . إن مثل هذه المعلومات وغيرها، لا شك ستساهم كثيراً في تفهم أكبر لمصايد الأسماك في البحيرة مما يتيح للقائمين على إدارتها القيام بالاستغلال الأمثل المستدام للبحير .

ومما لا شك فيه أن الالتزام بتحديد موسم لمنع صيد الأسماك من البحيرة من العوامل الأساسية للمحافظة على ثروتها السمكية، على أن يكون ذلك في ذروة موسم تكاثر البلطى النيلي ذى معدل النمو العالي . وحالياً يطبق منع الصيد في بحيرة ناصر اعتباراً من 15 مارس إلى 15 مايو . وقد تم في الدراسة الحالية تقويم فترة منع الصيد بالمقارنة مع سنوات لم يتم فيها المنع وقد وجد أن الزيادة في الإنتاج السمكي تقدر بحوالى 2.3 طن مركب شهر مما يثبت فاعلية تطبيق منع الصيد، والذى يرى المؤلفون أنه يجب أن يكون تاماً مع التقويم المستمر له و إعادة النظر في تحديد تلك الفترة إما بتمديدها أو تغييرها إذا ما دعت الضرورة ذلك .

ولتنمية الثروة السمكية في بحيرة ناصر، ينبغي ممارسة الاستزراع السمكى للاستفادة من المساحات الشاطئية الشاسعة وأيضاً المناطق المفتوحة من البحيرة والتى تمثل حوالي 0 % من

مساحتها. وقد خصص **الفصل الحادى عشر لعرض تجارب استزراع الأسماك في البحيـرة** ومناقشـة إمكانية إمداد البحيرة بزريعة بعض الأنواع من الأسماك وخاصة المستوطنة منه .

وقد سبق الإشارة إلى أن بحيرة ناصر تتميز بأخوار كثيرة غنية بهائمـات نباتيـة وحيوانيـة وكائنات قاع، كما توجد مساحات شاطئية شاسعة ومناسبة لتكاثر أسماك البلطي، أما الميـاه المفتوحـة والتى تمثل حوالي 0 % من مساحة البحيرة فهي غنية بالغذاء الطبيعي إلا أنها فقيرة في الأسماك، ولا تُمارس فيها عمليات الصيد بكثافة، وتخلو من أنواع الأسماك السابحة (pelagic) التـي تتغـذى علـى الهائمات .

وقد سجل حبيب وأوريجا (987) متوسط إنتاجية أولية لبحيرة ناصر تعادل 4.01 كجم وزن جاف) م/ عام، وبذلك يكون الإنتاج السنوى الصافى 10.3×10^6 و 21.0×10^5 طن وزن جاف ، وهذا يعادل إنتاجية سنوية للبلطي بحوالى 22.7×10^3 و 46.2×10^3 طن عندما يكون منسوب المياه في البحيرة 160 ، 180 متراً فوق سطح البحر على التوالي . وعلى الرغم من كل ما سبق ذكـره فلـم يتجاوز المصيد من الأسمـاك 20.6 ألف طن عـام 1997 , انخفض الى 19.2 الف طن عـام 1998 مع ارتفاع متوسط منسوب المياه فى البحيرة الذى تراوح بين 175.4 – 178.52 متـراً فـوق سـطح البحر .

لذلك بدأ التفكير جدياً في الاستفادة من القاعدة الغذائية الكبيرة والمتوفرة على مدار العـام فـي بحيرة ناصر عن طريق الاستزراع السمكي والذى يتركز في :

1 – استخدام المناطق الشاطئية في البحيرة وعلى وجه الخصوص الأخوار .

2 – الاستفادة من الغذاء الطبيعي في المياه الـ فتوحة باستزراع أسماك سابحـ .

3 – إمداد البحيرة بزريعة الأسماك – التى انخفضت إنتاجيتها – والهامة اقتصادياً مثل اللبيس، والبنـي وقشر بياض .

وللاستفادة من الأخوار كمرابي طبيعية للبلطيات أجريت تجارب لاقامـة مفرخـات لأسـماك البلطي النيلي لانتاج ملايين من الزريعـ . وأ كن التوصل إلى أنسب الطرق للحصول علـى الزريعـة وتغذيتها بغذاء طبيعي وصناعي للحصول على نسبة عالية تبقى على قيد الحيا . ووُجد أن أفضل عليقة للزريعة تلك التى تحتوي على 1.6 % بروتين على أن يكون معدل التغذية اليوميـة 0 % مـن وزن الزريعـ .

وأجريت بعض التجارب لمعرفة ثر إطلاق زريعة البلطي النيلي في أخوار بحيـرة ناصـر – مثلي خورى الرملة وكلابشه – على الانتاج السمكي بها، بعد مضي عـامين أو ثلاثـة مـن اطـلاق الزريعـ . ومما يدل على فاعلية هذا النوع من الاستزراع، زيادة انتاج الأسماك في مناطق الأخوار التى تم امدادها بالزريعة بما يعـ دل 6 % مقارنة بتلك المناطق التى لم تزود بها، علماً بأن منسوب المياه في البحيرة لم يتغير كثيراً خلال سنوات التجربـ . وللتوسع في هذه الممارسة يجب التقويم المسـتمر لهـا، بالإضافة إلى العناية بالزريعة بعد إطلاقها في الأخوار بمنع استخدام الشباك المخالفة، وعـدم تكثيـ فـ عمليات الصيـ .

كما أنه عند إنشاء مفرخات أسماك البلطي على امتداد بحيرة ناصر، يجب مراعاة تذبذب منسوب المياه حتى لا تغمر مياه الفيضان العالي تلك المفرخات مما يسبب إهداراً لتكاليفها إضافة إلى فقد الزريعـ .

ان استغلال منطقة المياه المفتوحة المياه العميق) في البحير، – والتى تمثل حوالى 0 % من مساحتها، والتى تعيش فيها أنواع محدودة من الأسماك النيلية مثل الراية وكلب السمك واللبيس والبني والبياض إلخ – تعتبر أمراً حيوياً لزيادة الثروة السمكي . وعلى وجه الخصوص أن هذه المنطقة تتميز بوفرة هائلة في الهائمات النباتية ، الحيوانية، والتى لا يوجد بها أنواع من الأسماك تستهلك هذه الهائمات، والتى عند موتها وتحللها تؤدي إلى إفقار مياه البحيرة في الأكسجين، عندما تغوص نحو القا . لذلك، وبناء على توصية العلماء اليابانيين، استقر الرأي على أن أنسب نوع يمكن تربيته في أقفاص في عرض البحيرة ويمكنه استهلاك الكميات الهائلة من الهائمات، هو سمك المبروك الفضي وذلك من بين أربعة أنواع مقترحـ). لذا يستعرض الفصل الحالي تجارب الإكثار الصناعي لهذا النوع باستخدام المحفزات الهرمونية للحصول على البيض والمني، ثم إخصاب البيض، وتربية اليرقات الناتجة حتى طور الزريعـ . وأمكن تربية الزريعة على هائمات حيوانية مثل جنس موينا *Moina* sp. حتى تصل إلى طول 15 مليمتر، ثم بعد ذلك يتم تغذيتها بهائمات نباتية مضاف إليها عليقة صناعيـ .

وقد أجريت تجارب لاستزراع زريعة المبروك الفضى في أقفاص توضع في عرض البحيرة بكثافات مختلفة فوجد أن متوسط الإنتاجية تتراوح من 2. –10.8 كج م ، ووزن 23. –1.62 كج للسمكة الواحدة وذلك في فترة 15 شهر . كما أوضحت التجارب أن معدل نمو زريعة المبروك الفضي المربى في أقفاص في جنوب البحيرة يكون أعلى منه من الزريعة المرباة في وسط أو شمال البحيرة، وهذا يعزز نتائج الدراسة أن المجرى الرئيسي للبحيرة في جنوب البحيرة يكون ذا إنتاجية أولية أعلى منها في المنطقتين الوسطى والشماليـ .

ويرى المؤلفون أن استزراع المبروك الفضي يجب أن يقتصر على الأقفاص العائمة مع الاحتياط الكامل حتى لا تنطلق صغاره في البحيرة نظرا لمنافسة المبروك الفضي لأسماك البلطى في نوعية الغذا .

وقبل تطبيق تربية المبروك الفضي في الأقفاص العائمة على نطاق واسع يجب الأخذ في الاعتبار مدى تقبل الشعب المصري لهذه النوعية من الأسماك كغذاء، نظراً لاحتواء المبروك الفضي على عظام كبيرة وأشواك صغيرة بين عضلاته، كما أنه ذو لحم طري إلى حد كبير، بالإضافة إلى الرائحة غير المقبولة بعد موته وتخزينـ . لذلك أجريت بمركز بحوث الأسماك في أسوان تجارب للتخلص من الرأس والجزء الأسفل من البطن والأنسجة الدهنية مع إزالة الأحشاء، ثم معالجتها بعد ذلك بتمليحها للتخلص من الرائحة والطعم اللاذ . وقد أمكن تحضير مستحضر على شكل أصابع سمكية (fish fingers) يمكن عرضه للاستهلاك كغذاء مقبو .

وبناء على مناقشة بين المؤلف الرئيسي وبعض العلماء المتخصصين اقترحوا إدخال أحد الأسماك السابحة وهو سردين تانجنيقا (*Limnothrissa miodon* - Tanganyika sardine) والتى مكنها المعيشة في المياه الشاطئية والمفتوحة أيضاً حتى عمق يصل إلى 0 –25 متراً، ويصل أقصى

طول لها 4 سم خلال عامين، وتتغذى على الهائمات النباتية والحشرات وأحياناً صغار الأسماك، وتتكاثر عندما يبلغ طولها . سم كما تعتبر فريسه سهلة لكلب السمك . وتم نقل وأقلمة سردين تانجانيقا إلى بحيرتي كاريبا وكيفو بافريقيا، ويعتبر هذا النوع من الأسماك من المحاصيل التجارية الرئيسية في بحيرة كاريبا، حيث يصل إنتاجه إلى حوالي 25 ألف طن عام وتتراوح أطوالها من 3 إلى سم .

ويرى المؤلفون أنه لا يجب نقل وأقلمة أى نوع من الأسماك الدخيلة إلا بعد إجراء دراسات تفصيلية ومتأنية والأخذ بما يراه المختصون والخبراء والاستفادة من نتائج إدخال تلك الأنواع في بحيرات أخري، لمعرفة ما يمكن أن يحدث من تأثير على النظام البيئي في بحيرة ناصر، قد يسبب ضرراً بالغاً يصعب، بل قد يستحيل، علاج . وليس أدل على ذلك من جربة إدخال أسماك قشر بياض في بحيرة فكتوريا في منتصف الخمسينات دون إجراء دراسات وافية مما أدى إلى تدمير بيئي للبحيرة نلخصه فيما يلى وذلك مما حدا أن نشرت مجلة سيانتيفك أمريكان في عددها رقم 2 الصادر عام 1999 أن المسمار الاخير الذى دق في نعش بحيرة فيكتوريا و إدخال سمك قشر بياض "):

– قضى قشر بياض الساموسر - فرخ) على حوالى 0 % من إنتاج أسماك البلطي بأنواعه المتعددة في بحيرة فكتوريا، التى كانت تتغذى على كميات كبيرة من الهائمات النباتية، أما الآن فهذه الهائمات تموت وتتحلل مما يؤدي إلى إفقار بحيرة فكتوريا في الأ سجين الذائب في مياهه .

– كان يتم تجفيف أسماك البلطي بأنواعه والمصيدة من بحيرة فكتوريا، قبل إدخال سمك قشر بياض، تحت أشعة الشمس وبدون استخدام أخشاب الغابات، أما حالياً فتستخدم هذه الأخشاب في تدخين أسماك قشر بياض وذلك يؤدي إلى إزالة الغابات والتصحر، وما يتبع ذلك من آثار مدمرة على التربة وجرفها إلى البحيرة، مما يؤدي إلى زيادة عكارته .

– كان هناك آثار اجتماعية بالغة الخطورة، فقد انتشرت البطالة بين محترفي صيد أسماك البلطي من أهالى المناطق المتأخمة للبحير .

– حرم سكان المناطق المحيطة ببحيرة فكتوريا من الاستفا ة من غذاء بروتيني رخيص أسماك البلطى بأنواع) مما أدى إلى انتشار سوء التغذية بين السكان .

لذلك نرى أنه من الأفضل إكثار أنواع الأسماك المستوطنة في بحيرة ناصر والتى انخفض إنتاجها مثل : قشر بياض، اللبيس، البني وغيره) سنة بعد أخرى . ولقد تمت محاولات للتفريخ صناعى لتلك الأسماك سابقة الذكر على نطاق محدود ولاقت نجاحاً، إلا أن الباحثين لم يتمكنوا من الحصول على كميات كبيرة من الزريعة تكفى لسد الاحتياجات اللازمة لامداد البحيرة بما فيها من أخوار، وعلى العموم يمكن الاستفادة من خبرة المتخصصين في هذا المجال والذين نجحوا في الإكثار الصناعي لتلك الأنواع على نطاق واسع، كما يجب الإكثار من الهائمات معملياً بكميات تكفى لسد احتياجات الزريعة التى تنتج من التفريخ الصناعى للأسماك سابقة الذكر، حتى يمكن تغذيتها وتربيتها حتى تصل إلى الحجم المناسب لنقلها إلى البحير .

ويتضمن **الفصل لثانى عشر** عرضاً عن بعض الفقاريات التى تعيش في البحيرة والتى تنتمي **للبرمائيات والزواحف والطيور** ، ومدى تأثيرها على النظام البيئي والثروة السمكية . مع إلقاء الضوء على بيولوجية تلك الفقاريات من واقع الدراسات عليها في البحيرات الأفريقية .

ومن الواضح عند بدء تكوين البحيرة وجدت بها بعض البرمائيات ممثلة في الضفادع بإعداد كبيرة، أما حالياً فلم تسجل أى دراسة وجود أى نوع من البرمائيات، ذلك لعدم توافر البيئة المناسبة لها، والأمر يستلزم إجراء مسح شامل لمناطق البحيرة المختلفة للتعرف على البرمائيات – إن وجدت – من حيث أنواعها وتوزيعها وكثافتها .

أما بخصوص الزواحف التى تعيش في بحيرة ناصر، فتمثلها ثلاثة أجناس هي : **التمساح النيلي، الورل النيلي، والترسة النيلية** . وفي السنوات الأخيرة أثيرت مشكلة تزايد أعداد التماسيح في البحيرة خاصة في أخوار المنطقة الجنوبية للبحيرة، وذكر بعض الصيادين أن التماسيح هاجمتهم، كما أنها مزقت شباك الصيد، بالإضافة إلى أنها تستهلك كميات كبيرة من الأسماك، لذلك تضمنت الدراسة الحالية عرضاً لبيولوجية التمساح النيلي وتتضمن : الغذاء، العادات الغذائية، النمو، التكاثر، وضع التمساح النيلي في سلسلة الغذاء، وأيضاً أثره في البيئة ومصايد الأسماك . وباستعراض تلك الدراسات يتبين لنا أن التماسيح تشغل جزءاً هاماً من النظام البيئي في البحيرة، كما أنها ذات فائدة كبيرة لمصايد الأسماك من خلال تغذيتها على كثير من الحشرات والقشريات والأسماك آكلة صغار الأسماك الهامة اقتصادياً، اضافة إلى لك يمكن للتماسيح أن تتغذى على بعض أنواع الطيور آكلة الأسماك والتى تستهلك كميات كبيرة من الأسماك في غذائها، وفضلاً عن ذلك فان فضلات التماسيح تزيد من المغذيات الذائبة في مياه البحيرة وهذا يؤدي إلى رفع الإنتاجية الأولية، وأحياناً تتغذى التماسيح على الحيوانات النافقة في البحيرة وبذلك تخلصها منه . أضف إلى ذلك أن بحوثاً عديدة أوضحت خطأ الزعم القائل بأن التماسيح تستهلك كميات كبيرة من أسماك البحير . ففي إحدى الدراسات وجد أن المتوسط اليومي لوزن الأسماك التى يتغذى عليها تمساح طوله –3 أمتار وهو الحجم الذى تكون فيه الأسماك النسبة الكبيرة فى غذاء التمساح) هو من نصف إلى كيلو جرام فى اليوم، كما سجلت دراسة أخرى متوسط عدد 0.56 سمكة في معدة التمساح الواحد . وفي عام 1996 شكل جهاز شئون البيئة لجنة لبحث مشكلة التمساح النيلي في بحيرة ناصر لدراسة مدى الأضرار التى يسببها للثروة لسمكية ولذلك صيد ستة تماسيح فحصت أمعائها، وتبين لأعضاء اللجنة أن أحد هذه التماسيح وطوله 76· سم تحتوى معدته على سبعة أسماك بلطى فقط، وذلك يدل على أن التقديرات الجزافية لغذاء التماسيح على أسماك كثيرة لا تمثل الواقع .

ومما يذكر أنه فى كثير من البحيرات التى تم يها حماية التماسيح، ازدادت ثروتها السمكية، على سبيل المثال : بحيرة ميراو (Mweru) بوانتيبى . حيث التماسيح فيها محمية وبها أعداد كبيرة من التماسيح، فقد لوحظ أن إنتاجيتها من أسماك البلطي مرتفعة، إذ أن التماسيح في هذه البحيرة تتغذى على القراميط المفترسة لأسماك البلطي الكبيره وصغارها أيض . كما لوحظ أنه في بعض مناطق جنوب روديسيا زيمبابوى) حيث تم إبادة التماسيح التى تعيش فيها، أدى ذلك لزيادة أعداد سرطانات المياه العذبة والتى تتغذى على البلطي، كما أنها تتلف شباك الصيد، وتهاجم الأسماك حتى وهي في شباك الصيد .

وقد أشار العالم كوت (Cott – 1961) – الذى قام بدراسات ضافية على التماسيح – إلى أن المناطق التى خفضت فيها أعداد التماسيح في زائير تضاعفت فيها أعداد المفترسات من الأسماك التى تحد من أعداد الأسماك ذات القيمة الاقتصادية .

ويوصي المؤلفون بضرورة إجراء دراسة تفصيلية عن عشار التمساح النيلي في بحيرة ناصر من حيث الكثافة، التوزيع، مناطق التواجد، الغذاء والعادات الغذائية له، الطفيليات التى تصيبه وعلاقتها بالطفيليات التى تصيب الأسماك، كما يرى المؤلفون تشجيع إنشاء مزارع للتماسيح في مناطق محددة على جانبي البحيرة، ذلك للاستفادة من جلد التمساح، ولحمه ودهنه وغيرها، كما يمكن أن تكون مصدر دخل كبير من السياحة، مع سن القوانين التى تسمح بصيد أعداد محدودة من التماسيح سنوياً وعلى وجه الخصوص الكبيرة منها .

وينتشر **الورل النيلى** في بحيرة ناصر، وقد يتجول على الشاطىء ويبتعد عن المياه لمسافات بعيدة حثاً عن الغذاء الذى يتكون من الحشرات، بيض التماسيح وصغارها، القوارض المنتشرة على جانبي البحيرة، هذا إلى جانب تغذيته على الأسماك، كما يصل طول الورل النيلي البالغ لحوالي 70 سم، ولا توجد دراسات مفصلة وكافيه عنه لذلك يرى المؤلفون ضرورة إجراء دراسات منتظمة ومفصلة عن كثافة الورل النيلي في البحيرة : عشائره، توزيعه، نموه، تكاثره وسلوكه وأيضاً أثره على النظام البيئي في بحيرة ناصر .

قبل بداية إنشاء السد العالى وتكوين بحيرة ناصر، كانت **الترسة النيلية** منتشرة على طول مجرى نهر النيل، أما حالياً فيقتصر وجودها على المنطقة جنوبية من بحيرة ناصر، وتتغذى على الأسماك، والقشريات والقواقع . كما تضع بيضها في فصل الربيع على شواطىء البحيرة و الأخوار، ويفقس البيض بفعل حرارة الشمس، وتخرج الصغار من الأعشاش وتتعرض لعوامل الإبادة منها الطيور، الورل وغيرها من العوامل الأخرى . ومن الملاحظ أنه لا توجد دراسة مفصلة على الترسة النيلية في بحيرة ناصر، لذلك نرى إجراء الدراسات اللازمة عليها للتعرف على كثافتها، انتشارها، غذائها، نموها وتكاثرها، وأيضاً موقعها في السلسلة الغذائية، وأثرها على بيئة البحيرة .

لقد اصبحت بحيرة ناصر منطقة جذب لكثير من **الطيور المائية** ، فقد ذكر بهاء الدين (1999) أنه رصد ما يربو على 56 ألف طائر خلال شهري يناير وفبراير عام 1995 في حوالى 10 % من مساحة البحيرة وقدر أعداد الطيور التى تقضي الشتاء في كل البحيرة بما يربو على 200 ألف طائر، مما يجعل بحيرة ناصر من أهم الاراضي الرطبة في مصر . وأشار إلى أن أكثر تلك الطيور شيوعاً هي : غطاس أسود الرقبة؛ بجع أبيض، زرقاي، حمراي ، كيش، صواي ونورس أسود الرأس . ومن الطيور المميزة التى تتوالد في منطقة بحيرة ناصر : الأوز المصرى، حداية سوداء، كروان سنغالى، قطقاط بني، زقزاق أبو زفر ، قنبرة متوجة، وفصية مازجة). كما تعتبر منطقة البحيرة هى المنطقة الوحيدة في مصر حيث تتوالد فيها طيور : أبو مقص أفريقى، أبو فصادة أبقع . والجدير بالذكر أنه تم رصد تدفق أعداد كبيرة من اللقلق أصفر المنقار والبجع الرمادى خلال شهور الصيف وقد لوحظ أن بعضاً من مجتمعات الطيور الأصلية مثل السميمة وثرثارة الشجر التى كانت منتشرة في المنطقة قد اختفت من المنطقة بعد تكوين بحيرة ناصر .

ونظراً لأهمية الطيور في النظام البيئي للبحيرة، فقد تضـمن الفصـل الثـانى عشـر معظـم الدراسات التى تمت عليها في منطقة البحيرة منذ عام 1981 وحتـى الآن، ففـى عـام 1981 سـجل ميز نجر ومولية 19 نوعاً من الطيور المائية في بحيرة ناصر، وفي الفترة 988 –1991 سجلت عبـد العزيز 122 نوعاً من الطيور على الجزر النيلية ووادى العلاقي والمناطق المتاخمة لبحيـرة ناصـر، وكان من بينها 17 نوعاً من طيور آكلة للأسماك . أما في عام 1994 سجل مينيجر وعطا 47 نوعاً من الطيور المائية في فصل الشتاء، ومما يذكر أن أعداد الطيور التى رصدت في المناطق الجنوبية للبحيرة كانت قليلة نسبياً، وربما يرجع ذلك إلى مساحة البحيرة الكبيرة وطول شواطئها المتعرج .

وفي عام 1998 سجل ثروت 41 نوعاً من الطيور في بحيرة ناصر منها 19 نوعاً من الطيور آكلة الأسماك .

وقد نوقش أثر الطيور المائية آكلة الأسماك على الثروة السمكية في بحيرة ناصر، خاصـة أن هذه الطيور يقتصر غذاؤها على الأسماك فقط، وقد قدر مكاوي (998) أن الطيور آكلة الأسماك فـي بحيرة ناصر تستهلك 2885.6 طن عام تمثل حوالى 5 % من الإنتاج الكلي من الأسـماك فـي عـام 996 ، إلا أن هذا الرقم مرتفع ومبالغ فيه ذلك لأن بعض أنواع الطيور المائيـة المسـتهلكة لأسـماك البحيرة والتى ذكرها مكاوي (998) في قائمته والتى تستهلك كميات كبيرة من الأسماك، اتضـح لنـا أنها ليست من أنواع الطيور التى تتغذى على الأسماك، كما أن معظم الطيور آكلة الأسماك قـد تكـون زائرة فقط فى فصل الشتاء أو غير مقيم . لذلك فإن هناك حاجة ماسة لإجراء دراسات أخرى تفصـيلية لتوضيح أثر الطيور المائية على الثروة السمكية في بحيرة ناصر، وكذلك دراسـة عـن مـدى تـأثير فضلاتها على إثراء البحيرة بالمغذيات التى تزيد من الإنتاجية الأولية للبحيرة، وأيضـاً دراسـة أنـواع الطفيليات التى تنقلها الطيور المائية للأسماك، وتعتبر عائلاً رئيسياً له . ومن الجدير بالذكر – كما سبق وذكرنا في الفصل الثامن – ملاحظه زيادة كبيرة في معدل إصابات أسماك بحيرة ناصـر بالطفيليـات وعلى وجه الخصوص بيرقات دفيلي الكونتراسيكم، والذي تنقله الطيور آكلة الأسـماك ويوجـد فـي القانصة، وقد تؤدي الاصابة به إلى موت بعض الطيور . لذلك فدراسـة دورة حيـاة تلـك الطفيليـات وكثافتها من الدراسات الهامة لاماطة اللثام عن الزيادة الكبيرة في الطفيليـات التـى تصـيب أسـماك البحير .

ولما كانت بحيرة السد العالى إحدى أربع بحيرات أفريقية صناعية تكونت في وقت متزامن لذلك تناول **الفصل الثالث عشر :** دراسة مقارنة عن **بحيرة ناصر والبحيرات الصناعية الأفريقية .**

تعد **بحيرة ناصر** أحد البحيرات الصناعية الكبرى في أفريقيا، وتكونت فى وقت متزامن مع ثلاث بحيرات أخرى هي **ولتا، كاريبا وكاينجى** . وتم دراسة مقارنة بينهم من عدة نواح تشمل : الصفات المورفومترية لكل منها من ناحية : الموقع، المناخ، وصف الخزانات المقامة عليها، وأيضاً الصفات الطبيعية والكيميائية : مستوى منسوب المياه، التوصيل الكهربى، الأس الأيدروجيني، الأملاح المغذية الذائبة في الماء، الهائمات النباتية والحيوانية، الطحالب العالقه والنباتات المائية، الإنتاجية الأولية، التنوع السمكي، تركيب المصيد من الأسماك، التغيرات في عشائر الأسماك ومتوسط الإنتاج السمكي .

ومن الملاحظ أن بحيرة ناصر خالية من النباتات المائية الضارة حتى الآن مثل ياسنت المـــاء ورد النيل) الذى ينتشر في بعض البحيرات الأخرى ويصعب التخلص منه لقدرته الفائقة على التكـــاثر والانتشار، ويسبب فقد كميات كبيرة من المياه عن طريق النتح قد تفوق أضعاف ما يفقد بالبخـــر، وهنا يجدر بالذكر أن كمية البخر في بحيرة ناصر تتراوح من 10 الى 16 مليار متر مكعب ســنوياً . لـــذلك يجب الملاحظة المستمرة والمتابعة للتدخل السريع فى حالة انتشار ياسنت الماء في بحيـــرة ناصـــر، أو غيره من النباتات المائية الضار ..

ومقارنة بالبحيرات الأفريقية الأخرى تعتبر بحيرة ناصر من أغنى البحيرات الصـــناعية فـــي إنتاجها الأولي، وتصنف ضمن البحيرات المخصبة (eutrophic ، وذلك نتيجة إثرائها بالأملاح المغذيـــة بسبب الترسيب المستمر للمواد العضوية التى تحملها سنوياً مياه الفيضان، وهـــى تعمل علـــى ازدهـــار الهائمات النباتية والطحالب العالقة الغذاء الرئيسى لأسماك البلطي). أما البحيرات الصـــناعية الأخـــرى في أفريقيا فيعزى انخفاض الإنتاجية الأولية بها إلى أن الماء الذى يصل إليها فقير في الأملاح المغذي .

وبمقارنة التنوع السمكي في البحيرات الصناعية الأفريقية الأربع، نجد أن في بحيرة ناصر تـــم تسجيل 23 نوعاً من الأسماك الشائعة تنتمي إلى 9 فصائل، أما في بحيرة كاينجي فيوجد بها 36 نوعـــاً تنتمي إلى 11 فصيلة، وفي بحيرة كاريبا يوجد 22 نوعاً من الأسماك تنتمي إلى 9 فصائل، أمـــا فـــي بحيرة فولتا فيوجد 37 نوعاً تنتمي إلى 12 فصيلاً .

أما بخصوص متوسط الإنتاج السمكي في بحيرات أفريقيا فهو كالتالى :

5.58 – 111.7 كجم هكتار عام في بحيرة ناصر؛ 5.4 –47.2 كجم هكتار عام في بحيـــرة كاينجي، 0 –57 كجم هكتار عام في بحيرة كاريبا، 43.4 كجم هكتار عام في بحيرة فولتا .

توصيات لمتخذى القرار والساسة والمخططين

ان الهدف من هذه الموسوعة التى استغرق إعدادها أكثر من 10 سنوات لـــيس هـــو مجـــــرد إعطـــاء الباحثين والدارسيـــن والمخططين والساسة ومتخذي القـــرار والمسئولين عـــن إدارة البحيـــرة وتنميتها والحفاظ عليها،عرضاً للدراسات المتاحة عن بحيرة ناصر قبل وبعد تكوينها، وليس فقط لوضع خطة عملية نحو استغلال هذه البحيرة الاستغلال الأمثل المتواصل لتكون مصدراً لغذاء بروتينـــي هـــام متمثلاً في الثروة السمكية فحسب، وإنما هو وضع الاقتراحات اللازمة للمحافظة عليها من التلوث، فهي الخزان الوحيد الذى يمد مصر بالحياة وأي تلوث فيه سيكون له عواقب خطير . لذلك من واقع ما جـــاء بهذه الموسوعة ومن تحليل الدراسات المختلفة نعرض الآتي ليمكن وضع استراتيجية لادارة البحيرة :

أولاً : إعلان منطقة بحيرة ناصر **محمية طبيعية** ، حيث تقنن فيها الأنشطة البشرية من استغلال للثروة السمكية، وزراعات شاطئية، وسياحية وغيرها، واستخدام كل السبل لمنع تلوثه .
وخاصة أن هناك دلائل لبدء هذا التلوث فيها :

– تكرارية ظاهرة الازدهار لطحلبي (algal blooms) والتى كانت قليلة الحــدوث فـــي بــدء تكوين البحيرة، وسجلت في مساحات محدودة ولفترات قصيرة قبل الفيضان في جنوب البحير . وحاليـاً تحدث طيلة العام وانتشرت بالبحيرة ولم تقتصر على الجنوب فقط ولكن امتدت لتشمل وســط وشــمال البحير . ومن المعروف أن الاز هار الطحلبي – من أهم أسبابه – زيــادة التخصــيب . لــذلك يــرى المؤلفون دراسة هذه الظاهرة باستفاضة وتحديد أسبابها والأنواع التى تسببها وأثرها على نوعية الميــاه والثروة السمكي .

ب – الزيادة الملحوظة في الإعداد الكلية للبكتريا عند درجتى 22 و 7؛ . . حتــى أنهــا زادت على ما يربو ألف مرة منذ بدء تكوين البحيرة، وذلك نتيجة تلوث البحيرة مــن قبــل الصــيادين وقــد يصرف فيها مياه صرف البواخر السياحية وغيره . لذلك يجب على متخذي القرار منــع مثــل هــذه الممارسات وإصدار القوانين المشددة نحو عدم صرف أي مخلفات بشرية أو ناتجة عن النشاط البشري في بحير . وكما سبق وأن ذكرنا أن التلوث مشكلة من الصعب التخلص منها إذا انتشرت في البحير . وربما يستفاد مما هو حادث فى بحيرات مصر الشمالية التى تعتبر الكلى بالنسبة للمجاري المائي .

حـ – زيادة تخصيب البحيرة (eutrophication) في السنوات الأخير .

ثانياً : يجب توحيد إدارة البحيرة، وإنشاء جهاز يضم جميع الوزارات والهيئات ومراكز البحوث التى تعمل في البحيرة، ولا يتخذ أى قرار إلا عن طريق هذا الجهاز والذى نقترح أن يضم نخبة من المتخصصين مثلاً : في البيئة، المعهد القومي لعلوم البحار والمصايد والري، المسطحات المائية، الأرصاد، الزراعة، اكاديمية البحث العلمي، الجامعات , اقسام الدراسات البحيرية والثروة السمكية ... الخ). ويحدد هذا الجهاز تكوين فريق بحثي متكامل من العلماء في شتي المجالات يقوم بتوجيه إجراء البحوث المتنوعه في جميع مناطق البحيرة المجري الرئيسي والاخوار , المياه الشاطئ ه وتحت الشاطئي). ثم يقوم بتحليل المعلومات التي توصلت اليها البحوث لابراز اثر العوامل المختلفة على الثروة السمكي . ومن مهام الفريق البحثي تحديد المخزون السمكي طبقاً للانتاج الحقيقي للاسماك وايضا الصيد التجريبي , وبالتالى يمكن تحديد أقصى انتاجية سنوية مستدا ه لكل نوع من الاسماك . كما يقوم الفريق البحثي بدراسة مشاكل البحيرة إن وجدت .

ثالثاً : إجراء دراسات تفصيلية عن بيولوجية الكائنات الحية النباتية والحيواني) وكثافتها وتوزيعها، وعلاقتها بالاسماك والفقاريات الاخري، ومدى تفاعلها مع الظروف البيئية، وتأثير تلك الظ روف عليه . ومن واقع هذه الدراسات يمكن تتبع السلسلة الغذائية وعلاقة المفترسات بمفترسيها ومدى تأثير البعض في البعض الآخر على ان يشمل ذلك الكائنات الموجودة بالبحيرة سواء في المياه أو الحيوانات القاعي .

رابعاً : دراسة مستمرة وتفصيلية للخصائص الطبيعية والكيميا ية لمياه البحيرة، والتعرف على دورات العناصر بها، وعلى علاقة هذه الخصائص بالدراسات البيولوجي . ومن الملاحظ أن معظم الدراسات التى أشرنا لها في الموسوعة الحالية محدودة تقتصر على جمع عينات من مناطق محدودة ولفترة قصير . لذلك فيجب التخطيط لعمل دراسة شاملة لمناطق البحيرة : المنطقة الشاطئية، وبعد الشاطئية ومنطقة المياه المفتوحة حيث المياه العميق ، وكذلك

رسوبيات القاع سواء في المجرى الرئيسي أو الأخوار . وعمل دراسة كاملة للأخوار المهمة والغنية بالغذاء الطبيعي والأسماك .

خامساً : استكمال الدراسات على النباتات المائية واستمرارها وعمل مسح لها للتعرف على توزيعها ومدي انتشارها، ورصد وجود أى نوع جدي . ووضع خطة كاملة لتحذير العاملين بالبحيرة من الصيادين ومسئولي الري للتبليغ عن ظهور أى نبات جديد، وخاصة تلك التى تعتبر آفه فى بحيرة ناصر مثل ورد النيل – والمنتشرة فعلاً في النيل جنوب وشمال البحير . لأنه من المعروف أن الفاقد من الماء بسبب النتح من هذا النبات قد يكون ضعف الفاقد بالبخر الطبيعي والذى يتراوح من 10 و 16 مليار م٣ .

سادساً : إجراء دراسات تفصيلية ميكروبيولوجية على البكتريا بالبحيرة سواء في الماء أو رسوبيات البحيرة بالمناطق الشاطئية والعميقة والأخوار على أن تكون دراسة متكاملة للتعرف على أنواعها وتركيزها وتوزيعها، ومدى تأثيرها على صفات البحير .

سابعاً : من الواضح من استعراض الدراسات على البحيرة والتى تضمنتها الموسوعة الحالية، أن هناك حاجة ماسة لدراسة منطقة المياه المفتوحة الدياه العميق ، وخاصة أن معظم الدراسات كانت تجرى على المناطق الشاطئية أو القريبة منه . فيجب دراسة هذه المنطقة وصفاتها والأحياء بها دراسة دقيقة والتعرف على أنواع وكثافة الأسماك بها، ويمكن في هذا الصدد استخدام السونار والتليفزيون تحت الماء للتعرف على التغيرات في هذه المنطقة . ومدى تأثير تحلل وموت الكميات الهائلة من الهائمات النباتية والحيوانية علي الاسماك .

ثامناً : يتضح من الدراسات المتاحة على العناصر الثقيلة والنادرة محدودية البحوث عليها، لذلك يلزم إجراء دراسات تفصيلية لتحديد تلك العناصر في كل أجزاء البحيرة من مياه ورسوبيات وفي المجرى الرئيسي والأخوار . ومدى تأثير تلك العناصر على الكائنات الحية وعلى وجه الخصوص الأسماك . والتعرف على كميات تلك العناصر في الرسوبيات ومدى زيادتها بفعل التخزين المستمر للمياه، وكذلك المبيدات إن وجدت .

تاسعاً : لما كانت الطفيليات التى تصيب الأسماك في تزايد مستمر، لذلك ينبغي إجراء دراسات تفصيلية عن هذه الأنواع ودورات حياتها، ومدى تأثيرها على نمو الأسماك وتكاثرها، وهل تنتقل للإنسان وما تأثيرها عليه . ودور الفقاريات الأخرى مثل الطيور والتماسيح والورل وغيرها كعوائل لهذه الطفيليات .

عاشراً : استمرارية الدراسات على فطريات البحيرة في المناطق المختلفة لأنه من المتوقع اكتشاف أنواع جديدة، للتعرف على خصائصها، ودورها في النظام البيئي . وقد يكون لبعضها تطبيقات اقتصادية .

حادى عشر : استمرار الدراسات البيولوجية على الأسماك للتعرف على أنواعها وكثافتها، ومعدلات نموها مع دراسة تأثير التخزين على انواع الأسماك ذات الأهمية الاقتصادية وعلى وجه الخصوص على معدلات النمو التى ثبت أنها تنخفض في البلطيات نتيجة للتخزين، وهل هذا ينطبق على الأنواع الأخرى من الاسماك؟ كذلك دراسة بيولوجية التكاثر وعلاقة

الأنواع بعضها بالبعض . مع دراسات ضافية ومستمرة عن تأثير منسوب المياه سواء على مناطق توالد البلطيات أو على الإنتاجية الكلية لها أو على كليهم .

ثانى عشر : التقويم المستمر للمخزون السمكي من واقع الإنتاجية الفعلية للبحيرة، وهـــو الأمر غير المعروف بالدقة حتى الآن . فاحصائيات هيئة تنمية بحيرة ناصر تشمل المسلم فعلاً لميناء السد العالي وهذا أقل بكثير من الأرقام التى تعلنها هيئة تنمية الثروة السمكية التى قد تزيد بمعدل 50 % عن الواقع بحجة تهريب الأسماك . لذلك يوصي المؤلفون باطلاق أسعار الاسماك المصيدة من بحيرة ناصر وتركها لآليات السوق للعرض والطلب، على أن تكون تحت رقابة من المسئولين، مع سن القوانين الرادعة التى تضمن عدم استنزاف مصائد البحيرة والإعلان على الإنتاجية الحقيقية من الاسماك الي جانب المصيد التجاري . إن عدم معرفة الإنتاج الفعلي حتى الآن لا يمكن المسئولين من الإدارة السليمة للبحيرة، لذلك لتحديد المخزون السمكي نقترح إجراء عمليات صيد تجريبية باستخدام أدوات صيد مختلفة على أن يكون ذلك بصفة مستمرة ولفترة مناسبة لتحديد المخزون وبالتالى حساب أقصي انتاجية مستدامة بدقة .

ثالث عشر : إعادة النظر في الفترة المحددة لقفل البحيرة، وتقييمها مع تنفيذ قوانين منع الصيد فيها بدقة، أو مدها لفترة أطول أو تغيير مواعيده . ويرى المؤلفون أن تحديد فترة لقفل البحيرة ومنع الصيد فيها من الممارسات الهامة لاعطاء فرصة للبلطي النيلى – ذى المعدل العالي للنمو – من التكاثر . كما يجب توعية الصيادين من خلال المشاركه في برامج عملية باهمية البحوث العلمية في رفع إنتاجية البحيرة من الاسماك .

رابع عشر : دراسة الطرق المثلى والاقتصادية والعملية لحفظ وتداول الأسماك لتقليل الفاقد منها واستخدام التكنولوجيا الحديثة في هذا الصدد، مع التوسع فى استغلال الجزء الجنوبي من البحيرة والغني بثروته السمكية حوالى مرة ونصف الجزء الشمالي).

خامس عشر : عدم إدخال أي أنواع من الأسماك المستقدمة الدخيلة) إلا بعد اجراء دراسات إضافية ومتأنية وبعد الأخذ في الاعتبار بيولوجية البحيرة والإنتاجية الأولية، وبعد استشارة الخبراء والمتخصصين، مع تقويم أى دراسات سبق تطبيقها في بحيرات صناعية أخرى لمعرفة تأثير استقدام الأنواع الدخيلة على البحير . وفي هذا الصدد يرى المؤلفون أن يعقد اجتماع يضم نخبة من العلماء العالميين مع العلماء المصريين والمتخصصين في مجال الأسماك ومع خبراء من نفس البلاد التى ادخلت في بحيراتها أسماكاً، قبل التفكير في ادخال أى نوع منها لبحيرة ناصر . كمـــا يجب النظر بعين الاعتبار للقيمة الاقتصادية للنوع المستقدم ودرجة تقبل المستهلكين له . ويفضل إكثار الأنواع المستوطنة من الاسماك مثل البني واللبيس وقشر بياض، بإكثارها صناعياً وتربية الزريعة ثم اطلاق إصبعياتها فى الأخوار .

سادس عشر : تتميز بحيرة ناصر – عن البحيرات الصناعية الأخرى – بوجود أخوار طبيعية عددها 85 خوراً، أوضحت الدراسة الحالية أنها أغنى في الكائنات من هائمات نباتية وحيوانية، وحيوانات قاعية ... الخ) من المجرى الرئيسي، وتعتبر من أغنى مناطق البحيرة في الثروة السمكية . لذلك يمكن الاستعانة ببعضها لتصبح مزارع سمكية، عن طريق إمدادها بالأسماك المستوطنة . ومع تنظيم عمليات الصيد والمحافظة على الزريعة، فان للتقويم المستمر

لهذه الممارسة أثراً حيوياً للتعرف على مدى فاعليته . وإن كانت الدراسات الأولية أثبتت فاعلية هذه التجربة ي الأخوار لزيادة إنتاجيتها السمكي .

سابع عشر : عند إنشاء مفرخات الأسماك، تدرس بدقة المناطق التى تقام فيها مع الأخذ فى الاعتبار أعلى منسوب للمياه في البحيرة، حتى لا تجرفها مياه الفيضان العالي .

ثامن عشر : إنشاء قاعدة بيانات تخزن فيها جميع البيانات عن البحرة والبحوث السابقة والجارية والمشروعات المستقبلي .

تاسع عشر : حيث إن التماسيح انتشرت بالبحيرة وعلى وجه الخصوص في الأخوار الجنوبية لذلك فدراسة بيولوجية التماسيح وعشائرها وأثرها البيئي على بحيرة ناصر للتعرف على أعدادها وتوزيعها، يمكن الاستفادة منها في إنشاء مزارع للتماسيح .

عشرون : تعتبر بحيرة ناصر من المناطق المفضلة لكثير من أنواع الطيور، ولذلك تلزم دراسات متكاملة وعلى فترة طويلة لدراسة أنواع الطيور وعشائرها وتوزيعها وأعدادها، وتأثيرها البيئى على بيولوجية البحيرة، وتأثيرها على الثروة السمكية، ودورها كـ وائل للطفيليات التى تصيب الأسماك . والجدير بالذكر ان صيد الطيور المائية في منطقة البحيرة خلال الشتاء يؤدى إلى إهلاك أعداد كبيرة من الطيور المحمية والنادرة، مما يستدعى حماية تلك الطيور والمحافظة عليها، ومنع صيده .

واحد وعشرين : أن تدعو مصر لتكوين هيئة و منظمة أو جمعية تضم الدول الأفريقية التى توجد بها بحيرات وعلى وجه الخصوص البحيرات الصناعية لتبادل الآراء والخبرات وبحث مشاكل تلك البحيرات للاستغلال الأمثل والمحافظة عليه , من خلال عقد المؤتمرات والندوات وورش العمل .

Chapter 1
General Characteristics

LOCATION

The Aswan Dam was built in 1902 and heightened twice in 1912 and 1934 to increase its storage capacity. Nevertheless, the stored water was not adequate for agricultural development and great amounts of flood water were released annually into the Mediterranean Sea. In 1959, the construction of a rock-filled dam started on the River Nile, 17 km south of Aswan, 900 km from Cairo, which created one of the largest man-made lakes in Africa - the High Dam Lake (Fig. 1). The Lake extends from the dam itself in the north to the Cataract at Dal, Sudan in the south. The major portion of the Lake lies in Egypt and is known as Lake Nasser, and Lake Nubia on the Sudanese side. Lake Nasser extends between latitudes 22° 00' - 23° 58' N and longitudes 31° 19' - 33° 19' E

The purpose of constructing the Aswan High Dam (**AHD**) was primarily to benefit the downstream side by controlling annual floods, provide irrigation to about two million feddans* and generate electricity. Indirectly, however, the upstream side has also benefited because of the formation of the lake, which has created great possibilities for fisheries, navigation, agricultural production and even tourism. The region from Aswan to Adindan, which was previously an undeveloped desert, is already developed by controlled use of water from the reservoir.

MORPHOMETRY

The whole reservoir extends about 496 km, 292 km for Lake Nasser and 204 km for Lake Nubia. The area of the reservoir at 180 m level is about 6275 km^2 of which Lake Nasser occupies about 5248 km^2. The mean depth of Lake Nasser at 160 m level is 21.5 m as compared with about 25.2 m at 180 m level.

---

*Hectare = 2.4 feddans = 2.471 acres.

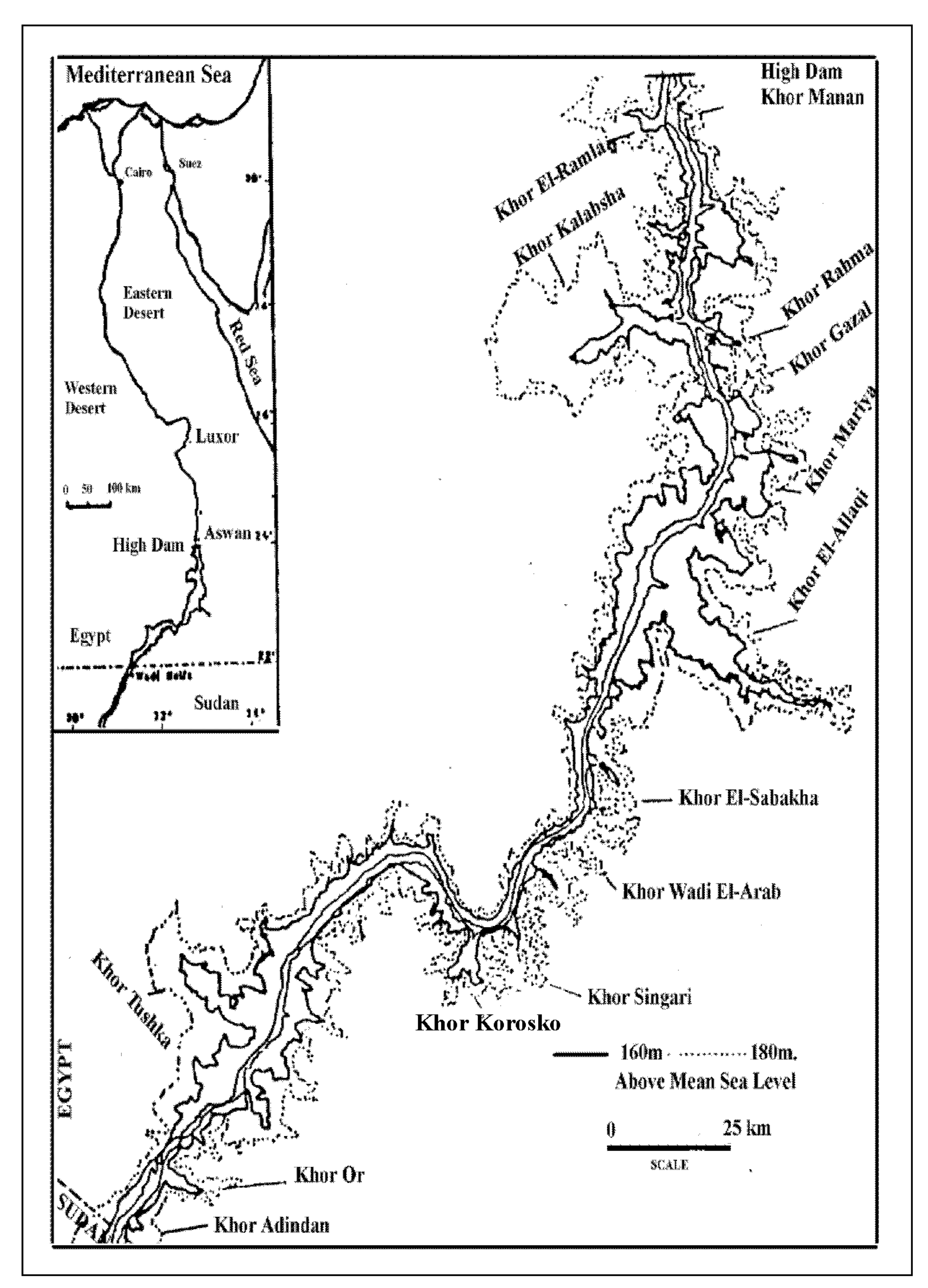


Fig. 1 **Map showing Lake Nasser with its major khors. The inset shows its location in Egypt.**

The mean width of the Lake at 160 m level is 8.9 km, and 18.0 km when the water level reaches 180 m. Morphometric data of Lake Nasser at water levels of 160 and 180 m are presented in Tables 1 and 2.

The deepest part of the Lake is the ancient river bed south the adjacent strips of cultivated land forming together the original river valley, called the central area of the Lake with its bottom elevation between 85 and 150 m above sea level. The side areas lie between 150 and 180 m A S L. The central part is considered as a flowing river-lake where the speed of the current is fast at the southern end of the Nubian gorge region (100-150 cm/sec). This speed is gradually reduced within a few kms to 10-20 cm/sec and in Lake Nasser to 0-3 cm/sec. The mean depth of this central part is gradually increasing from 10 m at the southern end to 70 m in the north. The bulk of the water masses coming from the south is passing through the central part, which forms about half of the total volume of the Lake (Entz 1976).

The flood, which arrived at Aswan from Khartoum within one month before the High Dam was built, covers now the same distance in not less than 5 months but sometimes probably more than 12 months depending on Lake level and the strength of the flood.

Comparing Lake Nasser with Lake Volta on Volta River, which was constructed in the same month and year of the Aswan High Dam (May 1964), shows that Lake Volta has a larger surface area (8700 km^2) than that of Lake Nasser. Also, Lake Volta has a greater volume (165 km^3) than Lake Nasser (153 km^3). Lake Nasser has a much more irregular shoreline (7,844 km), so its perimeter is much longer than that of Volta Lake (5,300 km). So, "Shoreline Index" values for Lake Nasser are greater than those for Volta Lake. The shoreline development value (DL according to Hutchinson) of Lake Nasser is extremely high (33.1) as compared with usual values of lakes ranging between 1.8 and 6 (Entz 1976). The mean depth of both lakes is almost similar (Lake Nasser 25 m, Volta Lake 19 m) as are their maximal depths (90 and 78 m respectively). But there is an important difference between their central areas, or main valleys. This area is much deeper and narrower in Lake Nasser than in Volta Lake, so it might play a much more important role in determining the flow of river water masses through the lake. In Lake Nasser the main valley might also be important for its relatively large area of muddy bottom and large quantities of original bottom fauna.

Lake Nasser has many embayments locally called khors (Fig. 2). The total number of important khors is 85 (48 on the eastern side and 37 on the western). Some khors as Kalabsha, Tushka and Allaqi are wide, with a sandy bottom and slope gently; others as Singari, El-Sabakha and Korosko are steep, relatively narrow with a rocky bottom. The total surface area of khors, as areas outside the main valley covered by water, is about 4,900 km^2 = 79 % of the total surface area, but in volume they contain only 86.4 km^3 water (= 55% of the total lake volume).

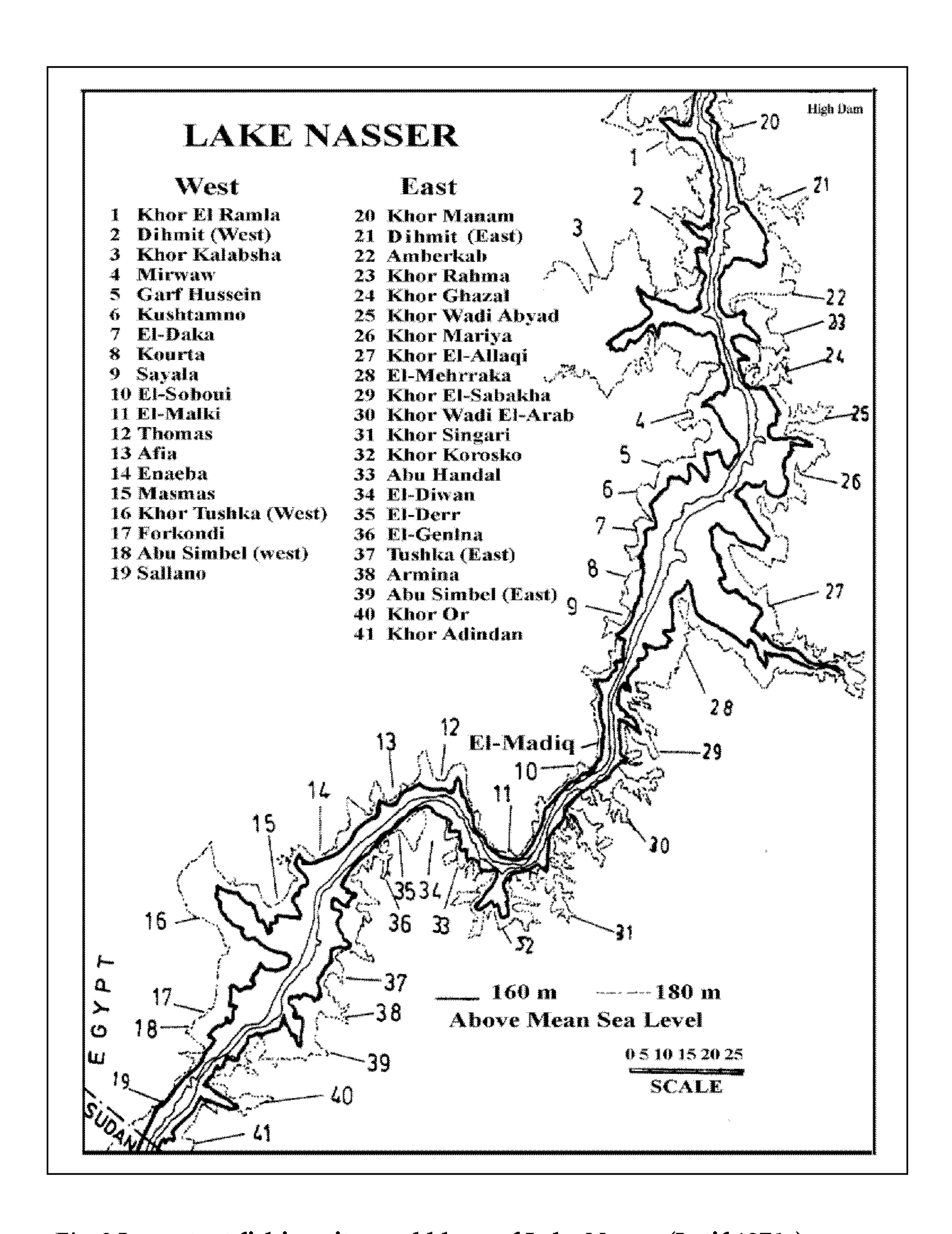


Fig. 2 **Important fishing sites and khors of Lake Nasser (Latif 1974a).**

ABIOTIC ENVIRONMENT

The water temperature fluctuates with air temperature, being high in summer and low in winter. In winter (i.e. November and December) the water temperature is usually uniform from the surface to the bottom at about 20 °C. In summer and early autumn the water temperature is different from the surface waters to the bottom ranging from 26-34 °C for the surface waters as compared with 15 - 21 °C in the bottom waters.

The transparency of the Lake water is affected by turbidity due to the presence of silt and clay (allochtonic inorganic materials) of riverine origin which are particularly strong in the flood season of the Nile, and the autochtonic suspended organic material (plankton and detritus), which flourish mainly in spring. Transparency in khors is normally less than in the main channel due to the abundant plankton populations.

Table 1 **Morphometric measurements of Lake Nasser at 160 and 180 m level (Entz 1976).**

	Lake Nasser	
	160 m	**180 m**
Length (km)	**291.8**	**291.8**
Shoreline (km)	**5380**	**7844**
Surface area (km^2)	**2585**	**5248**
Volume (km^3)	**55.6**	**132.5**
Mean width (km)	**8.9**	**18.0**
Depth (m):		
Mean	**21.5**	**25.2**
Maximum	**110**	**130**

The lake's water is completely oxygenated during winter and spring due to water circulation and the increase of phytoplankton, so it reaches 18 - 19 mg O_2/l (Aly 1992). In summer the oxygen concentration of the upper layer ranges from 6.0 to 11.2 mg O_2/l. Destruction of stratification takes place with the incoming flood water, particularly in the southern region of the reservoir. Then it extends to cover the northern region with the cooling of water.

The pH values of Lake Nasser are always on the alkaline side, the minimum value was recorded in summer, being 6.8 for the bottom water, and the maximum value was recorded in spring being 9.6 for the surface water.

As to the salt content of the water of Lake Nasser, N^+, K^+, HCO_3^-, Ca^{++}, SO_4^{2-}, PO_4^{3-} and available N_2 are higher than in Lake Volta (Entz 1970a). The concentration of sodium varies between 0.89 and 27.8 mg/l. Potassium range was 0.6 - 8 mg/l while the magnesium level ranged from 2.88 to 19.5 mg/l. The phosphate phosphorous ranged from 29.34 to 163 μg/l (0.074 - 0.522 mg/l dissolved phosphates). The silicate range was 8-35 mg/l (Elewa 1985b). Nitrate nitrogen, ammonia-nitrogen, nitrite-nitrogen and total organic nitrogen in the Lake ranged from 0.5 to 3.0 mg/l, 0.078 to 0.273 mg/l, and 9.44 to 14.45 mg/l respectively.

BIOLOGICAL DIVERSITY

Eleven macrophytic aquatic plants are recorded from the Egyptian Nubia pre- and post completion of Aswan High Dam. Two euhydrophytic species disappeared after Lake Nasser filling. Of the other 9 species, three *Potamogeton* spp. (i.e. *P. crispus, P. trichoides, P. pectinatus*) which were recorded

during the seventies and early eighties are no longer observed in recent years. The most common species are *Najas marina* subsp. *armata, N. horrida, Zannichellia palustris, Potamogeton lucens* and the macroalga *Nitella hyalina.* Recently *Myriophyllum spicatum* appeared in the Lake.

***Table* 2 Morphometric data of various sections of Lake Nasser.**

	Length of section (km)	Mean width (km) at levels		Mean depth (m) at levels		Surface area (km^2) at levels		Volume (km^3) at levels		Shoreline (km) at levels	
		160	180	160	180	160	180	160	180	160	180m
High Dam to Bab Kalabsha	61.94	6.79	13.92	22.17	25.05	422.8	864.5	9.38	21.69	1330	1829
Wadi Kalabsha (Bab Kalabsha) to Khor Mansour	--	---	---	12.90	9.88	442.3	553.9	0.27	5.47	113	464
Khor Mansour to Wadi El Allaqi	67.40	14.40	25.36	19.95	26.97	966.1	1707.2	19.29	46.06	1411	1774
Wadi El Allaqi to Ibrim (Khor Sabakha)	89.27	5.57	9.50	24.27	29.97	493.9	839.0	12.28	25.51	1651	2748
Ibrim to Abu Simbel	52.84	10.34	20.36	17.64	24.10	564.4	1075.7	9.60	25.89	732	846
Abu Simbel to Adindan	20.71	5.33	9.51	24.00	28.90	110.4	196.9	2.66	6.75	143	183

Lake Nasser is highly eutrophic and its primary productivity ranges from 4.32 to 128.15 $mgC/m^3/h$ during 1990 (Abdel-Monem 1995). The community of planktonic algae is diverse including 135 species constituting 54, 34, 33, 13 and 1 species, of Chlorophyceae, Bacillariophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae respectively. The blue-green algae mainly: *Oscillatoria, Phormidium, Anabaenopsis* and *Microcystis* spp., constitute the main phytoplankton in Lake Nasser. Diatoms, *Synedra, Nitzschia, Melosira, Navicula* spp. are common. Green algae are poorly represented, and *Chlorococcum agyptiacum, Legerheimia ciliata, Oocystis parva* and *Pediastrum simplex* (Abdel-Mageed 1995) are the dominant species in the Lake.

Twenty five identified and four unidentified species belonging to eleven genera of aquatic fungi are recorded in Lake Nasser. The fungal population of the Lake showed marked vertical variations. Of the mesophilic fungi, a total of 60 species and one variety belonging to 22 genera from both water (48 species, 1 variety and 16 genera) and bottom mud samples (40 species, 1 variety and 17 genera) have been recorded in the Lake. Moreover, 13 species and 1 variety belonging to 7 genera of thermophilic and thermotolerant fungi have been isolated from water (8 species, 1 variety and 3 genera) as well as from bottom mud (9 species, 1 variety and 6 genera) of Lake Nasser.

Microbiological studies of Lake Nasser show a remarkable increase of the total bacterial counts (TBCs) during the last two decades at all sites for both bacteria developed at 22 and 37 °C, amounting to more than 1000 folds. There is a gradual increase in TBCs from south to north with highest values near the

HD. Furthermore, four different genera with eight species of non-sulfur bacteria are recorded from the lake. The highest number of coliform and faecal coliform bacteria is recorded near the High Dam during winter.

The zooplankton population is mainly represented by typical limnoplankton forms, including 79 species dominated by Copepoda (10 species), Cladocera (10 species) and Rotifera (48 species). The zooplankton biomass (g/m^3) increases southward being the highest at Adindan, and decreases northward, being lowest in the vicinity of the High Dam (Latif 1983). At different localities, the zooplankton shows highest frequency in March, followed by August, while the least frequency prevails in June in the vicinity of the High Dam and in October at Amada and Adindan.

In Lake Nasser, the benthic fauna include 59 species dominated by insects (28 spp.), followed by molluscs (19 spp.), annelids (5 spp.), crustaceans (4 spp.) and cnidarians (coelenterates) and Bryozoa each is represented by one species. The benthos biomass is estimated as 44, 13.8, 8.2 and 6.0 gm/m^2 for Amada and 13.2, 16.1, 9.7 and 5.6 gm/m^2 for Adindan during March, June, August and October respectively (Latif, 1983).

Although 75 fish species (Bishai & Khalil 1997) known from the Nile system have been recorded, the fisheries of Lake Nasser depend upon only a limited number of species, viz., (in order of importance) *Sarotherodon galilaeus, Oreochromis niloticus, Hydrocynus forskalii, Alestes nurse, A. dentex, A. baremoze, Lates niloticus, Bagrus bajad, B. docmak, Synodontis serratus, Barbus bynni, Labeo horie, L. coubie, L. niloticus. Eutropius niloticus. Sarotherodon galilaeus, Oreochromis niloticus, Lates niloticus* and *Hydrocynus* spp. are adapted well to the new conditions and indeed have become the main specis in the Lake.

The mean water level increased from 130.17 m (above MSL) in 1966 to 174.49 m in 1979. Thus, the Lake's area expanded and the fish landings increased from 751 ton in 1966 to 27,021 ton in 1979, followed by another increase to a maximum of 34,206 ton in 1981, when the mean water level was about 174 m. Then, the mean water level decreased to 158.08 m in 1987, coinciding with a decrease in the total catch to 16, 815 ton in 1987. The fish landings resumed their increase to 30,838 ton in 1991, which coincides with an increase in the mean water level to 165.79 m in 1991. Another picture was observed during the period 1991- 1999. Thus, the mean water level increased progressively to a maximum of 178.92 m in 1999, accompanied with a sharp decrease in the total catch from 30,838 ton in 1991 to 13,983 ton in 1999 (Table 103). This is mainly attributed to that during the last 10 years, a large portion of the fish catch is sold illegally in the black market with high prices, and hence not recorded in the official catches.

GEOLOGY

Geological and stratigraphical studies dealing with the area surrounding the Lake were carried out by different authors (Ball 1902, El-Shazly 1954, Gindy

1954, Attia 1955, El-Ramly & Akkad 1960, Shata 1962, Said & Issawy 1964, El-Ramly 1973, Klitzch & Lejal-Nicol 1984, Latif 1984a, Hendriks *et al*. 1987, Gindy 1991 etc). The geological map of Lake Nasser and its surroundings is shown in Fig. 3. El-Ramly (1973) gave the following succession of the exposed and subsurface lithostratigraphic sedimentary units from bottom to top:

1. Lower Cretaceous Nubia Sandstone Formation (Aptian-Albian).
2. Upper Cretaceous Variegated Shells (Cenomanian-Santonian).
3. Upper Cretaceous phosphatic bed (Companion).
4. Upper Cretaceous Dakhla Shales (Maestrichtian-Danian).
5. Paleocene Kurkur Formation.
6. Upper Paleocene-Lower Eocene Garra Formation.
7. Lower Eocene Dungul Formation
8. Plio-Pleistocene gravel sheets.
9. Plio-Pleistocene Tufa deposits.
10. Pleistocene freshwater limestone.
11. Pleistocene calcite deposits.
12. Pleistocene Holocene playas.
13. Holocene sand dunes.

Klitzsch & Lejal-Nicol (1984) classified the sediments in Aswan area into the following rock formations arranged from bottom to top:

1. Aswan Formation.
2. Abu Aggag Formation.
3. Taref Formation.

Hendriks *et al*. (1987) studied the sediments in Aswan-Abu Simbel area and classified them into three formations arranged from bottom to top as follows:

1. Abu Aggag Formation.
2. Timsah Formation.
3. Umm Barmil Formation.

The Red Sea ranges, which are related to earth movements, form the backbone on the eastern side of the Lake region. The region is underlaid by a considerable thickness of sedimentary rocks, that lie on igneous and metamorphic rocks of Precambrian and later ages. The northeastern, southwestern and western parts of the Lake are covered by crystalline basement. Some volcanic exposures occur on the western side of the Lake associated with the crystalline basement.

The oldest sedimentary rocks exposed in this region are of the Early Cretaceous age (Aptian - Albian), and they crop out in nearly the entire southern Lake region. In the northern Lake region, they crop out in-between the crystalline bergs. Sedimentary rocks of Late Cretaceous and of Tertiary age are exposed on the northwestern side the Lake. In some areas, the older

sedimentary rocks and the volcanics are mantled by scree and detritus (desert pavement) or by recent alluvia in depressions and wadis.

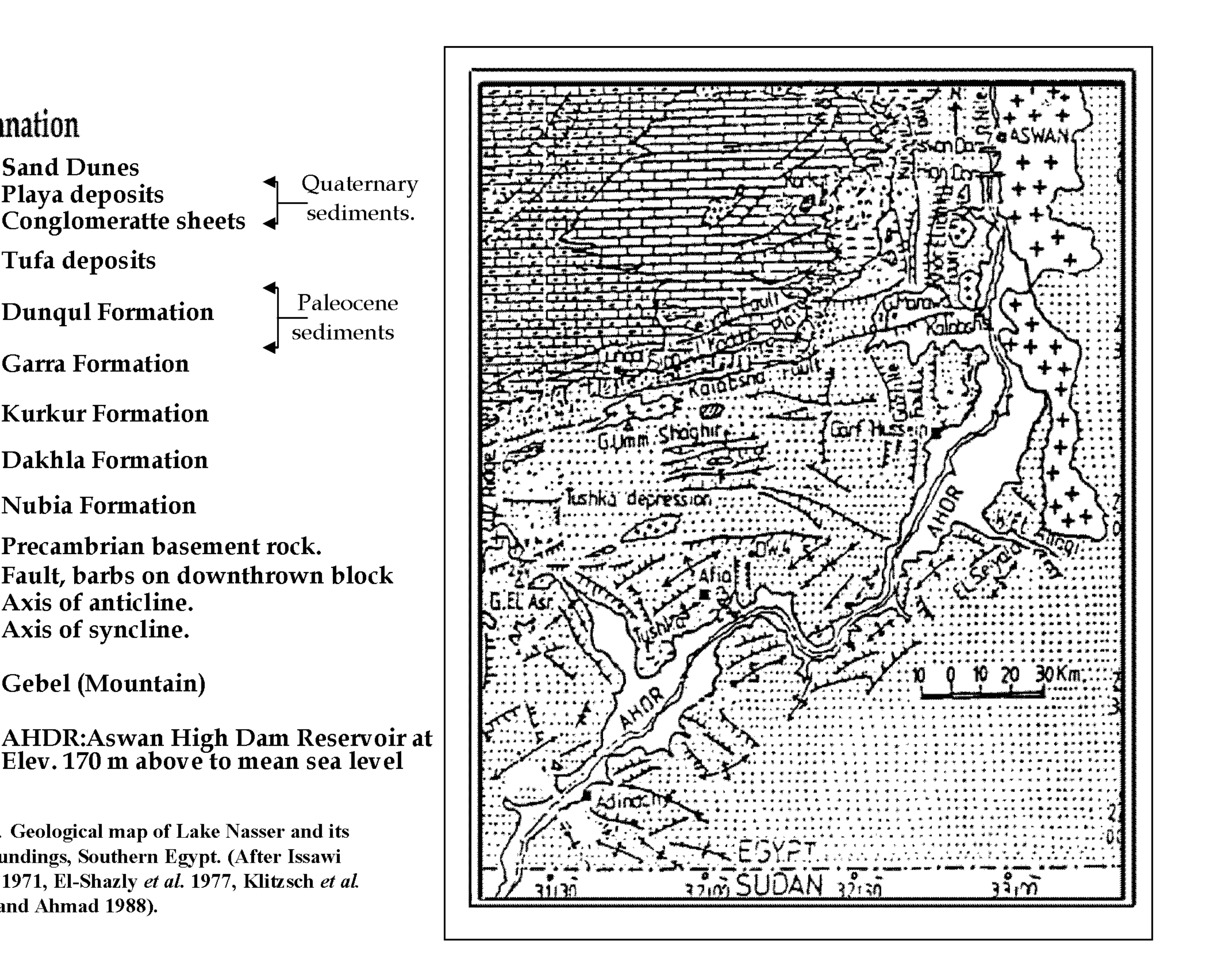


Fig. 3. **Geological map of Lake Nasser and its surroundings, Southern Egypt. (After Issawi 1968, 1971, El-Shazly *et al.* 1977, Klitzsch *et al.* 1980 and Ahmad 1988).**

The Nubian sandstone formation is mainly composed of sandstones, siltstones and clays. It varies in thickness from one locality to another in the lake region and ranges from 10 to 65 m along the stretch between the High Dam and Kalabsha to 592 m at the Sinn El-Kaddab graben on the northwestern side of Lake Nasser. In the Lake region, the majority of the topographic features date back to the Pliocene, and the present deep gorges and khors (wadis) together with the relief are probably of Pleistocene or Recent age. In this aspect, reference should be given to the direction of the old River Nile channel. The River Nile course followed different directions starting southward from Wadi Halfa until Aswan northward. In the sector, from Wadi Halfa until Thomas, it followed a SW -NE direction, between Thomas and El-Diwan, it followed a NW - SE direction, then a W - E direction from El-Diwan to Korosko. From Korosko northward, the old River Nile channel followed two directions, one SW-NE and the other SE - NW direction, following the main regional fracture lines in this sector of the channel. From Kalabsha northward until the High Dam site, it followed nearly one main trend of a S - N direction. It appears that the igneous and metamorphic rock exposures on both sides of the old Nile channel control the direction of this channel in this sector. The area at El-Madiq forms a deep canyon where the rocks are highly slicken-sided.

The increase in water level causes the inundation of new lands on both sides of the Lake, and their extent depends on the slope. Thus, extensive areas of the wadis having gentle slopes are covered with water with increased storage. Under these circumstances, the water causes leaching of salts especially the first time the lands are inundated. In turn, the Lake's soils had originated from the weathering of the geological formations within the Lake's area or from water drainage since ancient times. The salt composition of the soils shows that the predominant anions are sulphate and chloride; carbonate may be in traces but bicarbonate may also be encountered. The predominant cations are sodium and calcium, but potassium and magnesium may occur to a less extent. The possible salt forms are NaCl, Na_2SO_4, $NaHSO_4$, $CaCl_2$ and $CaCO_3$ (Abdel-Salam *et al.* 1974a, b).

The Nubian sandstone aquifer reflects the presence of these salts, but to different degrees in the different water samples according to the interpretations of El-Ramly (1973). Na^+ and Cl^- are predominating in some samples while, Ca^{2+}, CO_3^{2-}, and HCO_3^- show an increase in other samples. Mg^{+2}, CO_3^{2-}, HCO_3^- and SO_4^{2-} are evident in some other samples. According to Shata (1979), the initial salinity on some of the production wells in Wadi Kurkur (along the northwestern bank of the reservoir) is of the order of 1500 mg/l.

CLIMATE

Air Temperature. Lake Nasser is situated on the eastern side of the great Saharan belt, bordered on the north by the Mediterranean belt (winter rainfall) and on the south by the tropical belt (mostly summer rainfall). The area,

including Lake Nasser, receives no rainfall except for occasional thunderstorms which sporadically penetrate the area in winter.

During the period 1974 - 1975 the mean annual air temperature was 25.7 °C (Table 3), means of summer (June to August) and winter (December to February) temperatures were 32.6 and 16.8 °C (Table 6). January is the coldest month and July is the hottest (Table 4). The annual amplitude is from 8.1 °C to 46.2 °C (Table 3).

In 1985 the air temperature fluctuated between a minimum value of 11.5 °C at stn. 3 in January and a maximum value of 35.5 °C at stn. 6 in July (Fig. 4 and Table 4). In 1997 the monthly average values of air temperature ranged from 15.1 °C in February to 34.9 °C in July (Table 5) The mean annual values ranged from 22.1 °C at stn. 5 to 25.2 °C at stn. 6 (Fig. 4 and Table 4). The mean annual value of six stations in the Lake was 23.1 °C (Fig. 4 and Table 4).

The average seasonal values of air temperature for the region, examplified by Aswan during 5 periods (1974/1975; 1976/1978; 1983, 1984 and 1997) are shown in Table 6. Generally, the mean air temperature increases from February to July and remains almost constant till September, with a progressive decrease till the end of the year. The mean annual air temperature was almost the same (i.e. 25.7 and 25.6 °C) during the periods 1974/75 and 1976/78 respectively. Then, the mean annual air temperature decreased to 23.3 °C in 1983. Afterwards, it increased to 25.3°C in 1984 and 26.3 in 1997 (Tables 5 & 6).

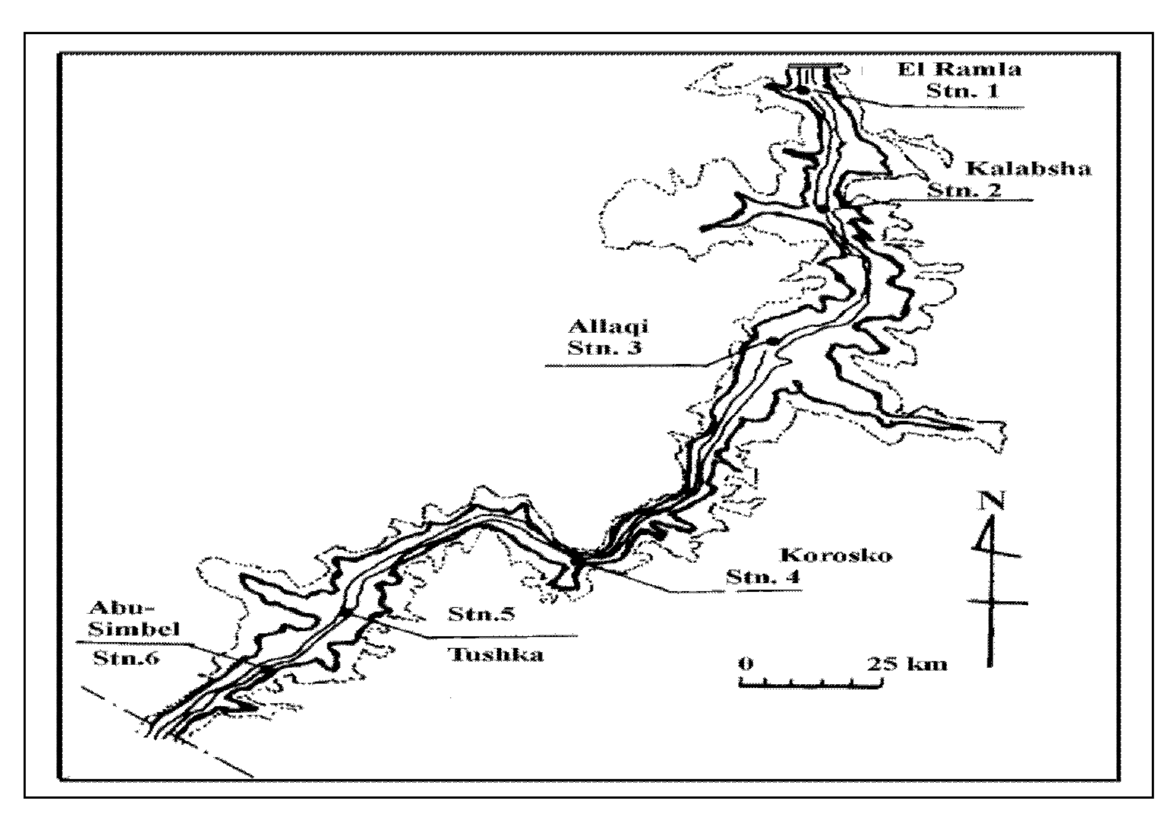


Fig. 4 **Location of stations in the main channel of the High Dam Lake.**

Table 3 **Air temperature of Aswan during (1974 - 1975) and 1997 (in parentheses).**

Month	**Air temperature °C**					
	Max.		**min.**		**mean**	
Jan.	23.5	(25.0)	**8.1**	(11.5)	**15.5**	(18.0)
Feb.	26.2	(21.9)	9.6	**(8.6)**	17.8	(15.1)
Mar.	30.5	(26.9)	13.0	(13.6)	22.0	(20.4)
Apr.	35.3	(34.6)	17.9	(18.6)	26.9	(26.9)
May	38.7	(39.2)	21.4	(24.3)	30.4	(31.7)
June	37.0	(41.5)	20.3	(26.4)	28.7	(34.7)
July	**41.1**	**(42.2)**	24.8	(27.3)	35.5	**(34.9)**
Aug.	41.0	(41.0)	24.8	(26.7)	33.5	(34.1)
Sept.	39.5	(39.5)	22.6	(24.4)	31.1	(31.9)
Oct.	36.4	(35.3)	19.6	(21.6)	27.7	(28.4)
Nov.	29.8	(29.9)	14.6	(15.8)	21.8	(22.6)
Dec.	25.0	(24.1)	9.7	(10.9)	17.0	(17.2)
Mean annual					25.7	(26.3)

In spring, summer and autumn the average values of air temperature decreased progressively during the periods 1974/75, 1976/78 and 1983 as shown in Table 6. Another picture was observed in winter, when the mean air temperature increased from 16.8 °C in 1974/75 to 19.0 °C in 1984 (Table 6).

Latif (1984a) reported that the Lake's microclimate shows an air temperature lower than Aswan, especially during summer months, the daily range for Aswan being 6 to 10 °C as compared with a range over the Lake of 0.5 to 4.5 °C. The seasonal variation of air temperature in 1985 (Fig. 5) shows that the daily minimum air temperature was about 5 °C (between 4 and 6 am) from January to February, while the daily maximum air temperature was about 25 °C between 2 - 4 pm during these months. The temperature began to rise considerably in March and its range was between 15 °C and 33 °C. The air temperature was between 21 °C and 44 °C from June to August, and was between 15 °C and 30 °C in autumn.

Belal *et al.* (1992) mentioned that the mean annual air temperature is 25.9 °C. Mean for summer is 31.9 °C, and for winter is 17.1 °C. Thus, the mean annual air temperature increased progressively from 1983 to 1993, being 23.1; 25.3 and 25.9 °C in 1983, 1984 and 1993 respectively.

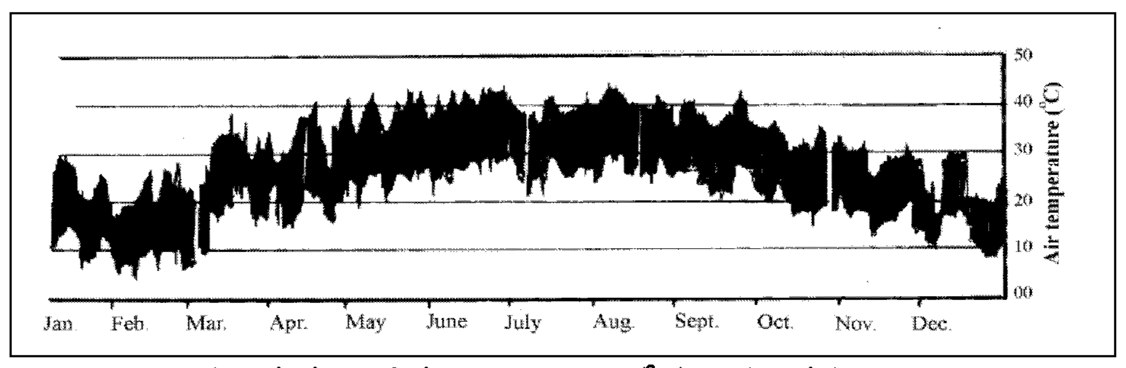


***Fig.** 5* **Seasonal variation of air temperature (°C) at the Fishery Management Center in 1985 (Abdel-Rahman & Goma 1992b).**

Table 4 **Monthly and mean annual variations of air temperature (°C) at six stations of Lake Nasser in 1985 (Abdel-Rahman & Goma 1992b).**

Month	Station						
	1	2	3	4	5	6	Monthly average
Jan.	18.5	14.5	11.5*	15.5	13.4	18.9	15.4
Feb.	11.8	18.8	22.4	14.5	17.5	18.1	17.2
Mar.	18.6	15.6	12.6	15.5	12.5	16.4	15.2*
Apr.	26.3	23.4	21.5	22.2	24.0	31.0	27.7
May	25.0	29.5	23.6	25.3	23.5	25.5	25.4
June	24.6	25.4	31.1	29.5	25.5	30.0	27.7
July	26.7	27.0	33.0	30.4	27.0	35.5**	29.9**
Aug.	24.4	27.5	27.5	28.5	30.5	29.3	28.0
Sept.	29.4	25.8	30.0	30.8	26.8	31.0	29.0
Oct.	24.5	22.5	21.1	25.6	22.4	23.0	23.1
Nov.	22.1	22.3	19.5	22.9	21.3	21.5	21.6
Dec.	19.5	17.3	15.5	23.4	21.1	22.4	19.9
Mean	22.6	22.5	22.4	23.7	22.1*	25.2**	23.1

* and ** designate minimum and maximum values, respectively. For stations refer to Fig. 4.

Relative Humidity. The relative humidity is highest (i.e. 40 - 41%) in December and January, and lowest in May and June, being 13 - 15 % and in turn is slightly higher over the lake than in Aswan (Latif 1984a).

Table 5 **Average monthly values of air temperature (°C) of Lake Nasser Area.**

Month	Year				
	1974 - 1975	1976 - 1978	1983	1984	1997
Jan.	15.5	14.8	15.4	22.1	18.0
Feb.	17.8	17.7	17.2	16.5	15.1
Mar.	22.0	21.0	15.2	23.5	20.4
Apr.	26.9	26.8	27.7	24.8	26.9
May	30.4	31.0	25.4	30.2	31.7
June	28.7	32.7	27.7	27.3	34.7
July	35.5	33.3	29.9	31.4	34.9
Aug.	33.5	32.1	28.0	29.2	34.1
Sept.	31.1	30.7	29.0	28.2	31.9
Oct.	27.7	28.5	23.1	28.5	28.4
Nov.	21.8	21.0	21.6	23.7	22.6
Dec.	17.0	17.1	19.9	18.5	17.2
Mean annual	**25.7**	**25.6**	**23.3**	**25.3**	**26.3**

Table 6 **Average seasonal values of air temperature (°C) of Lake Nasser Area.**

Season	Year				
	1974 - 1975	1976 - 1978	1983	1984	1997
Winter	16.8	16.5	17.5	19.0	16.8
Spring	26.4	26.3	22.8	26.2	26.3
Summer	32.6	32.7	28.5	29.3	34.6
Autumn	26.9	26.7	24.6	26.8	27.6
Mean	**25.7**	**25.6**	**23.3**	**25.3**	**26.3**

Wind Speed and Direction. Data based on regular meterological observations in Aswan and in Wadi Halfa (Omar & El-Bakry 1970), Entz (1976) during 1969 - 1974 and those of Latif (1984a and b) show the following :

1. All the year round the wind speed does not vary greatly, as the mean value ranges from 8 - 10 knots (15-19 kmh^{-1}), while the mean value for the whole year is around 9 knots (17 kmh^{-1}).

2. The prevailing wind is mostly NW-NE, blowing along the main channel or towards the lake center in the khors of the western side and towards the shore in the opposite eastern khors, causing leeward surface currents in different areas.

3. Between March and June strong easterly winds may blow usually reaching 10-15 m/sec (36-54 kmh^{-1}) or sometimes 18 - 20 m/sec (64.8 - 72 kmh^{-1}) accompanied with increased temperatures and followed by hot southerly winds. Sandstorms may occur in June and July or sometimes earlier (Latif 1984a). Stronger winds during winter causes complete water circulation.

4. During summer months moderate winds are common, interrupted frequently by shorter or longer calm periods especially in July and August which promotes a stable stratification of the Lake. In July an average of 46.4% of the days are calm. In winter under cooling weather conditions the wind is helping to destroy the lake stratification.

Moderate but sometimes remarkable wind induced surface currents are detectable in the Lake down to 3 - 5 m depth. Their direction in the central channel is from north to south, i.e. just opposite the main south-north current of the Lake, with a massive flow of water following the Nile valley towards the High Dam.

In special localities wind induced upwelling movements are recorded replacing the surface water masses blown away by the wind pressure. Such areas with upwelling currents are characterized by reduced water temperatures and oxygen saturation, low pH values and sometimes remarkable high transparency up to 600 or probably 800 cm Secchi values. Such conditions are frequently recorded near the High Dam, and sometimes at the southern end of the valley near Amada (200 km from HD), and almost regularly at the end of khors on the western shores. Entz (1976) points out that wind induced sinking water movements are present in other localities resulting in the accumulation of warmer water masses rich in oxygen with high algal turbidity and high primary production. This phenomenon could be observed in erosion littorals e.g. in khors of the eastern shore of Lake Nasser (Singari and Korosko, 180 km from HD), as also in Gorge region of Lake Nubia, near the previous Second Cataract (360 km from HD). Such peculiar conditions diminish the depth of the

metalimnion under upwelling and increases it under descending water movement.

The speed of wind induced currents could reach 10 to 35 cm/sec. The above scheduled system of currents covering practically the whole surface of the reservoir may be an effective way to avoid any gradual increase of salinity despite the extremely high rate of evaporation.

Another action of wind or even a slight breeze is its remarkable direct cooling effect on the surface water temperature. Wind is enhancing already high rate of evaporation, under conditions of extremely low relative humidity (of ± 35 % in winter and only 13 - 21 % in summer) to about 3,000 mm/year. These phenomena may explain the relatively low surface water temperature (16.0 - 33.0 °C) under extremely high ambient temperature of the surrounding desert (40.0 - 52.0 °C) in summer time (Table 15).

Evaporation. Because Lake Nasser is located in an arid region, evaporation results in a significant water loss. Several methods were used to determine the evaporation in Lake Nasser. Sharf El Din & El-Shahawy (1980) estimate evaporation from Lake Nasser by the mass transfer method (Sverdrup 1937 and Penman 1962 equations). The monthly evaporation has the maximum value of 40.95 cm (13.7 mm/day) in September and minimum value in January: 16.21 cm (5.2 mm/day). The total annual evaporation is about 359 cm. Adopting the Dalton, combination and Pan approaches Omar & El-Bakry (1970) calculated the daily minimum, maximum and average evaporation as 8.0, 8.3 and 8.1 mm/day respectively. They mentioned that maximum monthly evaporation values occur in September and minimum in February. The High Dam Authority estimates the evaporation from the Lake as 10 km^3 annually at 180 m level, thus representing a decrease in water level by 2 m at the surface area of 5000 km^2. A model of impoundment evaporation processes estimates a loss of 12.5 km^3 per annum, assuming unchanging surface area of 5000 km^2 for impoundment (Gishler 1976) (Table 7a).

Table 7a **Evaporation in Lake Nasser.**

	Max.	Min.	Average	Author
Daily evaporation (mm/day)	8.3	8.0	8.1	Omar & El-Bakry (1970)
	13.7	5.42	--	El-Shahawy (1975)
	13.7	5.2	--	Sharaf El-Din & El-Shahawy (1980)
Monthly evaporation (cm/month)	40.95		16.21	Sharaf El-Din & El Shahawy (1980)
Annual evaporation (cm/year)		359		Sharaf El-Din & El Shahawy (1980)
Annual water losses km^3	10			High Dam Authority
	12.5			Gishler (1976)
	14			Harb & El-Bakry (1979)
	16.4 (Actual)			Aboul-Ata (1978)

21.6 (Calculated)	Aboul-Ata (1978)

El-Shahawy (1975) figured that the maximum evaporation from the Lake is 13.7 mm/day in September and a minimum of 5.42 mm/day in January (Table 7a). Harb & El-Bakry (1979) pointed out that the annual lake evaporation is around 7.3 mm/day. At the Lake water level of 175 m, the total water loss by evaporation will not be more than 14 milliard m^3, which is about 11% of the Lake content. Aboul-Ata (1978) concluded that the values of actual water losses from the Lake were lower than the calculated theoretical values and estimated as 16.4 (actual) and 21.6 km^3 (calculated) for 1975 respectively (Table 7a).

In a later study (Abu-Zeid 1987), the average monthly evaporation is estimated by the heat budget method (E_B) and bulk aerodynamic method (E_H), using monthly estimations of different meteorological elements over the Lake based on more recent measurements (Table 7b). The results indicate that the mean daily evaporation maximum is in June (about 10.9 mm/day), and the minimum in January (about 3.8 mm/day). The mean daily value of evaporation for the year as a whole is 7.35 mm/day. The highest evaporation occurs between June-September, when evaporation is 45 percent of the total yearly value.

Table 7b **Mean daily values (mm) of evaporation calculated by the heat budget method (E_H) and by the bulk aerodynamic method (E_B). (Abu-Zeid 1987).**

Month	E_H	E_B
Jan.	3.59	3.93
Feb.	4.95	4.08
Mar.	5.40	4.77
Apr.	5.52	7.32
May	8.95	9.31
June	11.66	10.11
July	10.42	10.01
Aug.	8.39	10.68
Sept.	8.61	10.47
Oct.	6.98	7.83
Nov.	4.87	5.17
Dec.	4.90	4.52
Mean	**7.35**	**7.35**

ORIGIN OF WATER

The River Nile is the creator of fertile land in Egypt. It has sustained the existence of the fertile land and supported man's early civilization. In view of the increasing population from 20 millions in 1952 to 38 millions in 1977 to 61.4525 millions in 1996 (about 63 millions in 1999), the availability of water has

been a determining factor between prosperity and famine in Egypt when the Nile yield has been subjected to dramatic changes from one year to another.

During the pre-damming period (from 1869 to 1961) the mean annual flow of the River Nile at Aswan was 90.9 km^3. Aboul-Ata (1978) reported that the annual water supply varied from one year to another between about 42 km^3 in 1913-1914 to about 151 km^3 in 1878 - 1879. The average flow rate at Aswan for this period ranged from 14,000 m^3s^{-1} in 1878 to 275 m^3s^{-1} in 1922. It was difficult to maintain sufficient agricultural production, due to the extreme variations in the Nile flow. Low floods were below agricultural requirements and high floods inundated the land and caused property damage. Hence, the Aswan Dam was built in 1902 for regulating the flood and water storage for subsequent use. It was heightened twice in 1912 and 1934. Previously, about 40% of the Nile's average annual yield was lost in the Mediterranean Sea.

For Egypt, there are different origins of the Nile water. Out of an annual average yield of $84x10^9m^3$, the highly turbid flood water from the Ethiopian Plateau catchment region contributes 84% of the total supply. The annual Nile flood during the period from July to September used to be directly discharged to the sea prior to the construction of the AHD. The remaining 16 % consists of clearly distinct non-turbid water originating from the equatorial lakes region of Africa.

Table 8 **Hydraulic projects of the Nile (Mancy 1978).**

	Distance from AHD (km)	Year of completion	Reservoir capacity (10^9m^3)
Owen Falls Dam (White Nile)	4431	1954	120
Gebel El Aulia (White Nile)	1879	1937	5.5
Rosaries Dam (Blue Nile)	2459	1967	3.0
Sennar Dam (Blue Nile)	2193	1925	1.0
Khashm El Girba Dam (Atbara)	1513	1966	1.3
Old Aswan Dam	65	1902	5.2
Aswan High Dam (AHD)	0	1964	168.9
Jonglei Canal	--	--	--

Table 9 **Annual maximum, minimum and average water levels (m above MSL) of Lake Nasser during the period 1964 - 1999.**

Year	Water level (m)			Year	Water level (m)		
	Max.	Min.	Aver.		Max.	Min.	Aver.
1964	126.80	105.94	116.37	**1982**	172.63	170.18	171.41
1965	132.66	115.74	124.20	**1983**	169.86	165.64	167.75
1966	141.32	119.20	130.17	**1984**	169.42	162.97	166.20
1967	151.08	133.48	142.28	**1985**	164.34	156.16	160.25
1968	156.55	145.29	150.92	**1986**	163.61	156.14	160.38
1969	161.29	150.80	156.05	**1987**	161.66	154.50	158.08
1970	164.88	153.81	159.35	**1988**	168.82	150.62	159.72
1971	167.64	159.65	163.65	**1989**	169.79	164.30	167.05
1972	165.30	162.49	163.90	**1990**	169.50	163.72	166.61
1973	166.32	158.20	162.26	**1991**	169.35	162.23	165.79
1974	170.64	161.00	165.82	**1992**	170.75	163.84	167.30
1975	175.71	165.60	170.66	**1993**	174.32	167.24	170.78
1976	176.55	172.42	174.49	**1994**	177.28	169.51	173.40
1977	177.21	171.69	174.45	**1995**	176.93	172.32	174.62

1978	177.49	172.44	174.97	**1996**	178.55	172.28	175.76
1979	175.95	173.03	174.49	**1997**	178.52	175.40	177.38
1980	176.22	171.18	173.70	**1998**	181.30	174.66	178.13
1981	175.96	171.13	173.55	**1999**	181.60	175.66	178.92

The Nile is at present the only major river in the world which is totally controlled and fully utilized. This was achieved by an extensive Egyptian-Sudanese River Programme, which included six dams, the Jonglei Canal, seven barrages, and the Aswan High Dam (Table 8). Under the present flow control programmes, at present less than ½ billion m^3 is discharged directly to the sea. The Egypt's share from the Nile is 55.5 billion m^3/year, which is supposed to increase by 4 billion m^3/year after the construction of Jonglei Canal, southern Sudan.

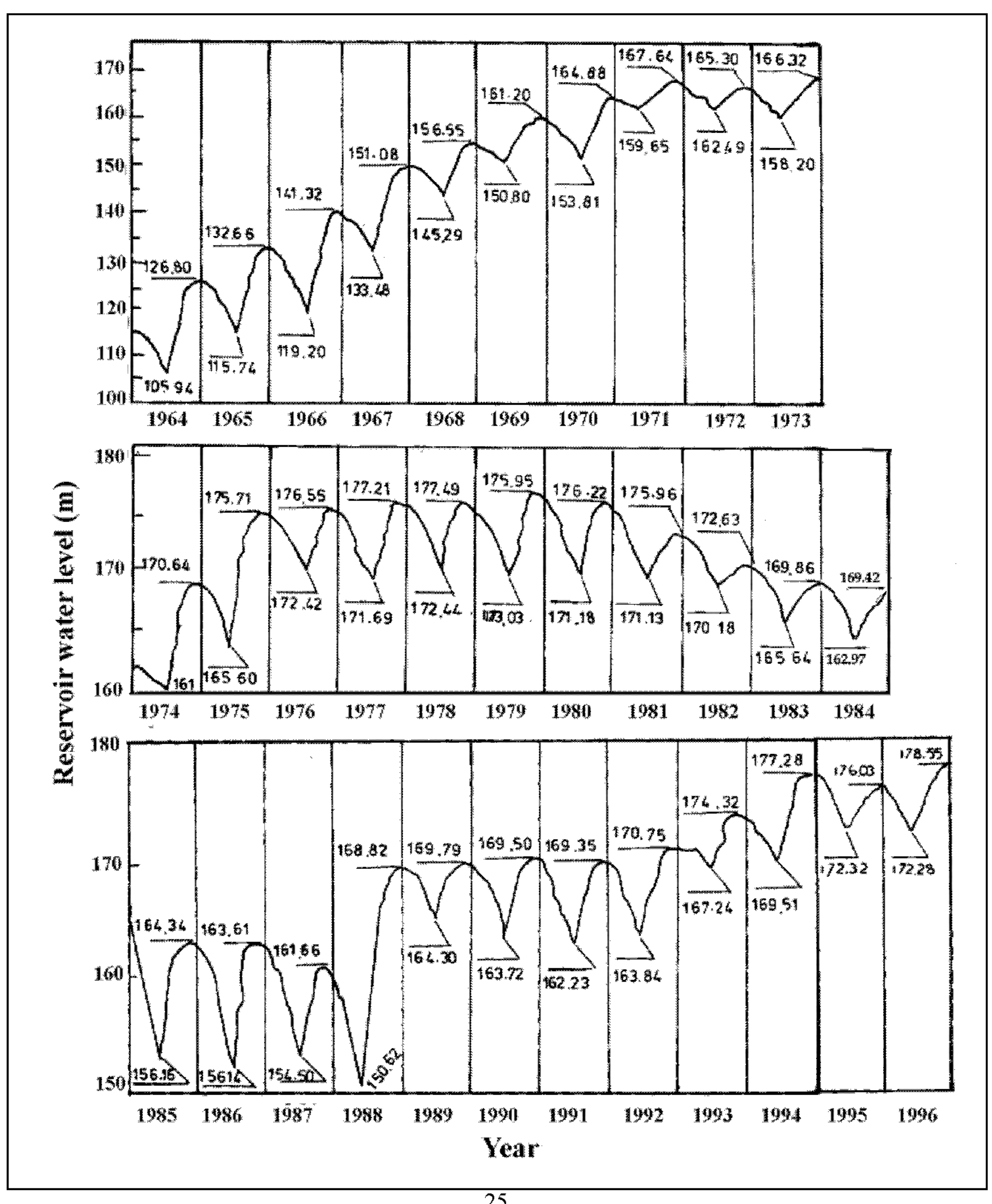


Fig. 6 **Water level of Lake Nasser (1964 - 1996).**

HYDROLOGY AND SEASONAL FLOWS

The river channel was diverted to its new path on May 15, 1964, after the completion of the first stage of AHD construction. The water level in the reservoir increased progressively through successive years (with the exception of 1972) (Table 9 and Fig. 6). The maximum operation level of 175 m above MSL was reached on October 13, 1975 and 175.63 by the end of the year (El-Darwish 1979). The final storage level is 183 m and, to safeguard the dam against exceptionally high floods, an important rule for the operation of the AHD is not to exceed 175 m level by the end of July (before the arrival of the new flood), thereby allowing for sufficient reservoir capacity to receive high floods. At the live storage of 175 m above MSL, the reservoir holds about 140.5 km^3, while the size of impoundment at 183 m above MSL is approximately 171.9 km^3.

The water level in the reservoir reaches its maximum in November and December of each year, then decreases gradually till the second half of July (dry period) (Figs. 7 and 8 and Table 10). When the flood water reaches the reservoir, the level starts to increase again. Recently, in 1999 the water level reached 181.60 m above sea level, which is considered as one of the highest records since the construction of AHD.

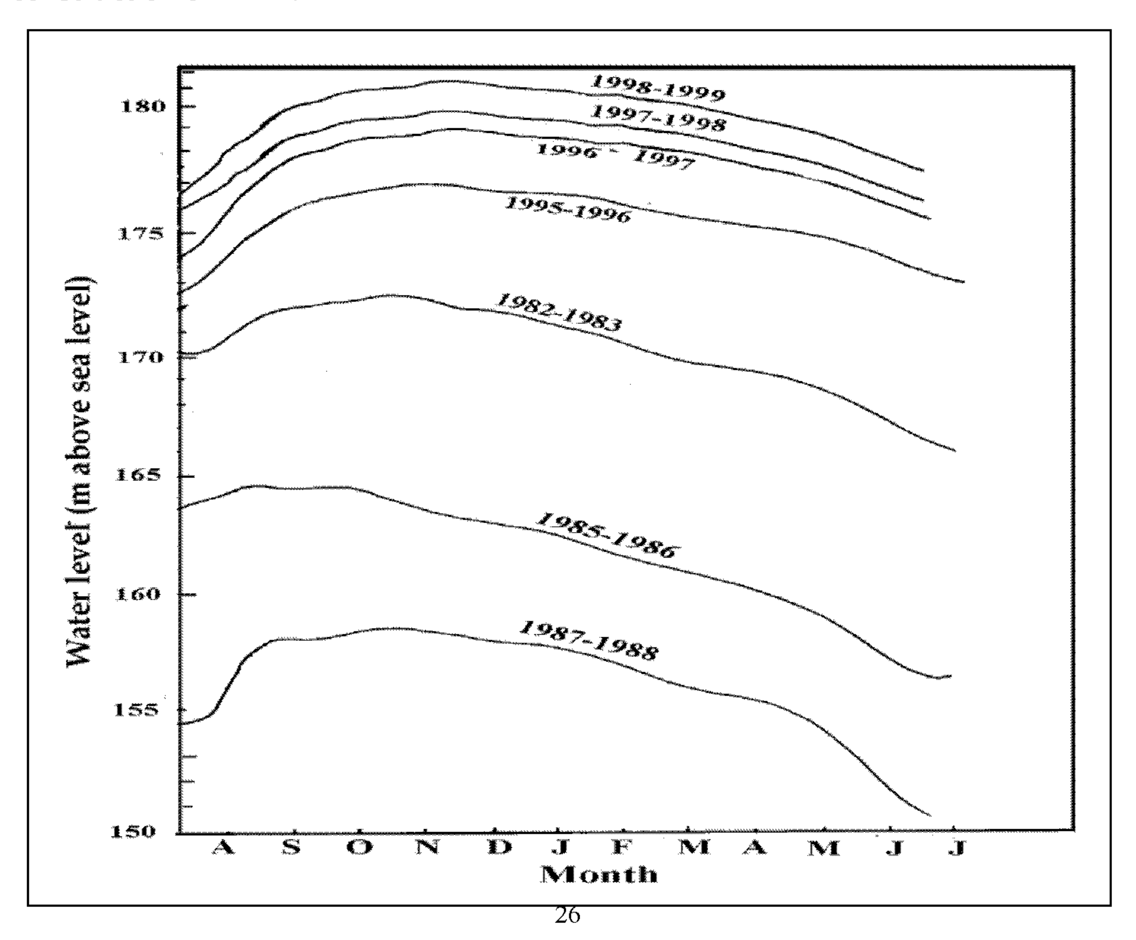


Fig. 7 **Level of Lake Nasser during the period 1982 - 1999.**

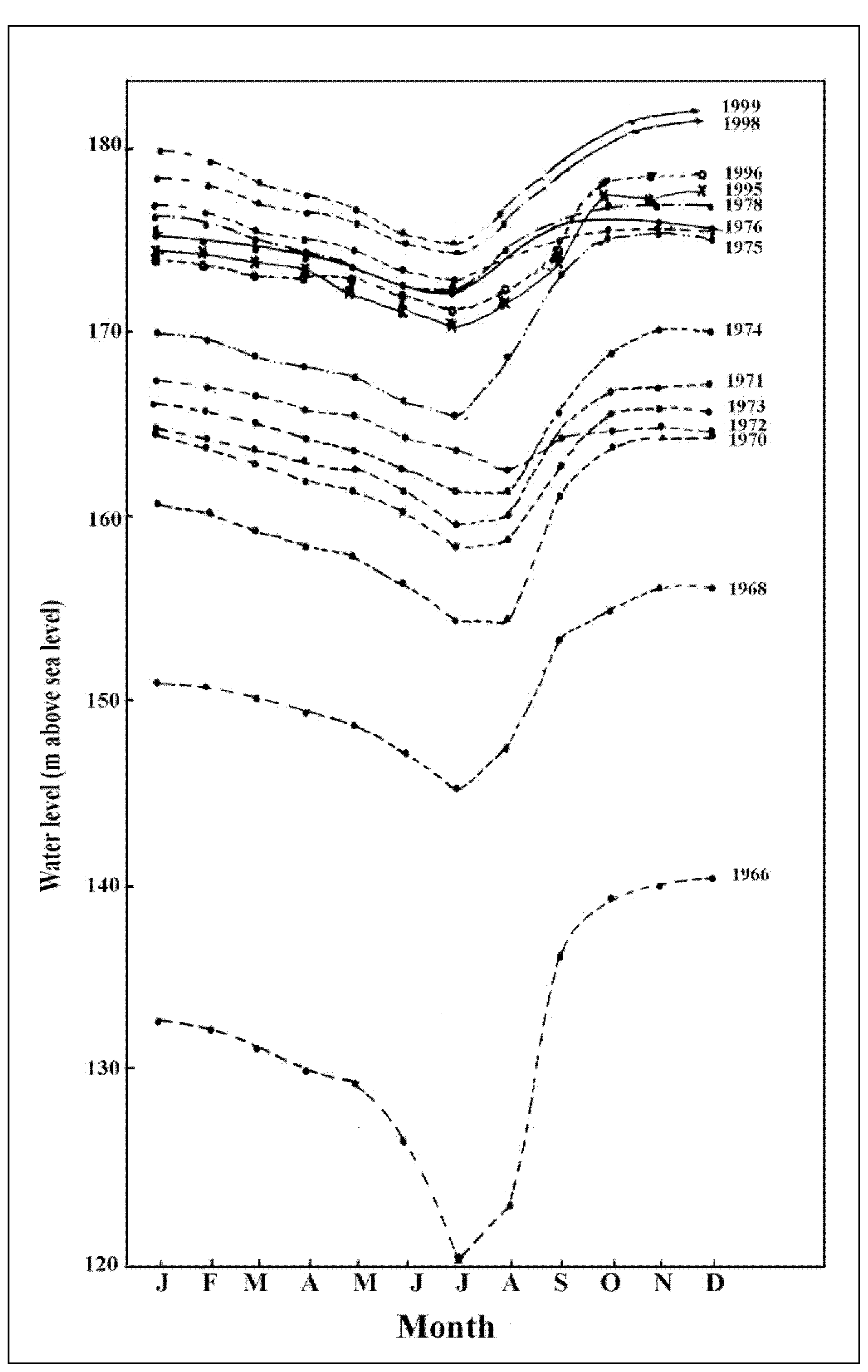


Fig. 8 **Monthly levels of Lake Nasser during 1966 - 1999.**

Table 10 **Monthly maximum and minimum water levels (m above MSL) in Lake Nasser during 1996 and 1997 (in parentheses) & 1999 (bold type).**

Month	Minimum	Maximum	Average	1999
Jan.	175.69 (178.52)	175.88 (178.32)	175.79 (178.45)	**180.23**
Feb.	175.27 (178.31)	175.69 (178.00)	175.48 (178.16)	**179.67**
March	174.60 (177.98)	175.26 (177.48)	174.93 (177.74)	**178.98**
April	174.04 (177.46)	174.58 (177.15)	174.32 (177.31)	**178.23**
May	173.34 (177.13)	174.03 (176.61)	173.69 (176.94)	**177.55**
June	172.35 (167.58)	173.33 (175.65)	172.84 (176.11)	**176.59**
July	172.28 (175.62)	172.69 (175.40)	172.49 (175.49)	**175.81**
Aug.	172.81 (177.11)	175.28 (175.51)	174.05 (176.14)	**176.83**
Sept.	175.39 (177.79)	177.79 (177.06)	176.59 (177.63)	**179.63**
Oct.	177.81 (178.00)	178.53 (177.72)	178.17 (177.88)	**180.78**
Nov.	178.50 (178.39)	178.55 (177.96)	178.53 (178.17)	**181.53**
Dec.	178.52 (178.52)	178.54 (178.40)	178.53 (178.51)	**181.19**

The High Dam provides complete control of the river flow. At present the river flow is maintained at a rather constant rate throughout the year. This is of the order 100 million m^3 day^{-1} (Figs. 9 - 11). Hence, downstream - north of the High Dam - the abnormally high turbidity of the Nile during the flood season before 1964 is now suppressed with control and storage of flood water in the reservoir whereby turbidity varies within narrow limits through the whole year (Figs. 9 and 10).

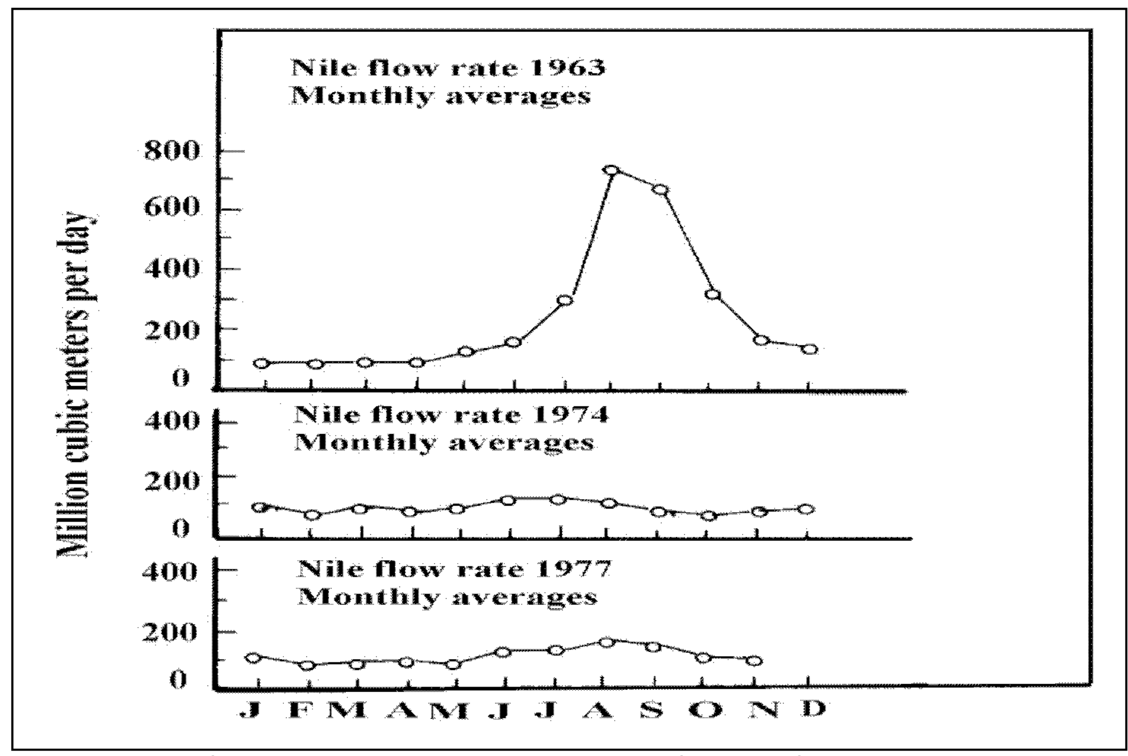


Fig. 9 **Comparison between average flow rates in the Nile before and after the High Dam construction (Ramadan 1978).**

Water discharge and storage. Since 1968, all excess water has been stored in the reservoir. The volume of water accumulated increased from 13.4 km^3 in 1968, to 87.3 km^3 in 1971, but decreased due to low flood to 76.7 km^3 in 1972 (Fig. 11). Then followed a continuous increase (Fig. 11). The pattern in total storage and outflow along the period from 1966 to 1978 could be followed from Fig. 11 (Elewa 1980).

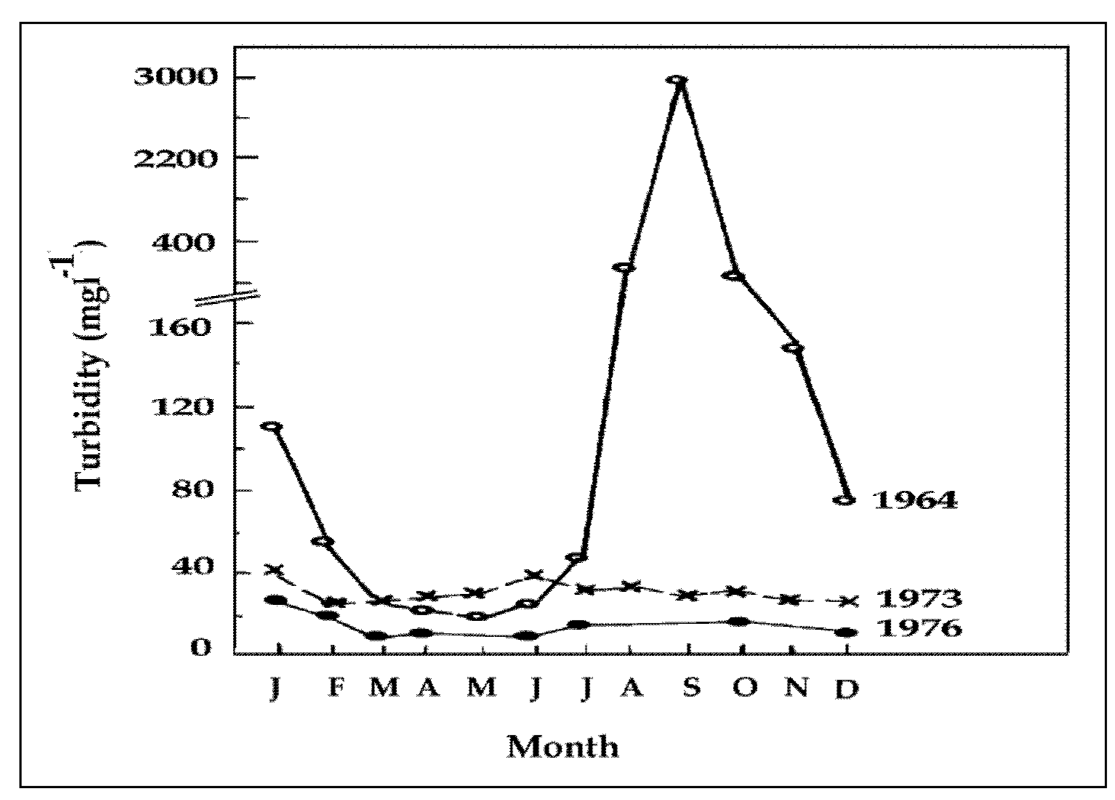


Fig. 10 **Average variations of turbidity in Nile waters (Ramadan 1978).**

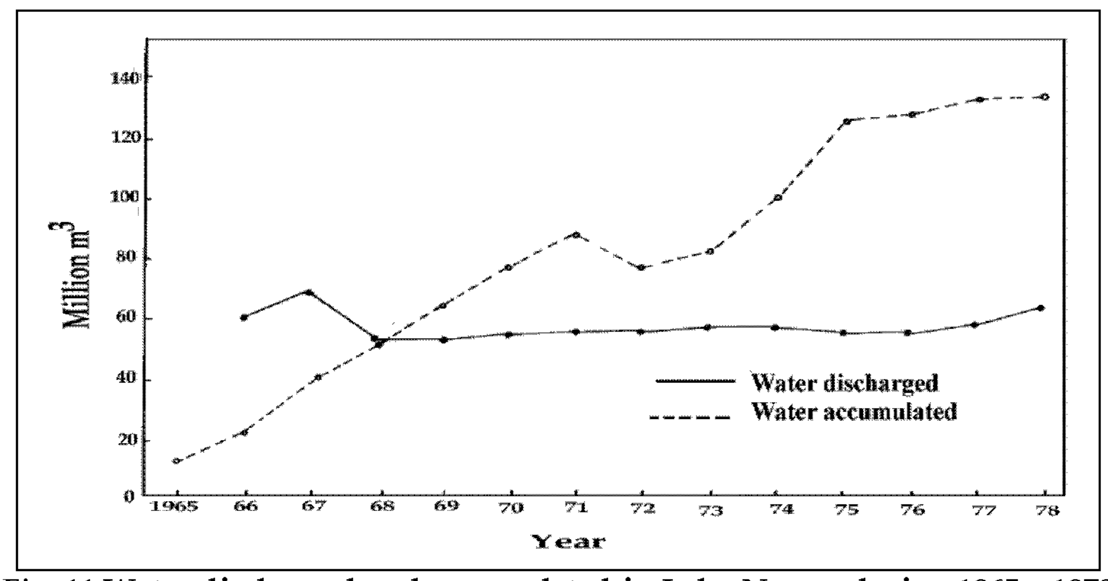


Fig. 11 **Water discharged and accumulated in Lake Nasser during 1965 - 1978 (Elewa 1980).**

Chapter 2
Sedimentation

BEFORE CONSTRUCTION OF ASWAN HIGH DAM (AHD)

At the beginning of the twentieth century, geologists were interested in the Nile Delta (Zaghloul 1976). Surface geologic work shows that the delta area is covered by recent alluvium of several meters thickness, This is underlain by coarse sand and gravels with occasional clay lenses of Pleistocene. Their total thickness ranges from 200 to 500 m. It generally increases towards the north and thins on both east and west. On top and towards the sea, the section changes to silt and clay.

According to information given by Herodotus and Strabo (fifth century B.C., first century A.D.), the Nile Delta has six or seven tributaries (Fig. 12A) during Pharaonic times. Thus, the suspended load of the Nile was discharged over a much wider geographic area than in recent years. Between the fourth and ninth centuries A.D., the discharge of the Canopic and Sebennitic Branches gradually decreased and finally ceased. At present, the Delta has only two branches, namely the Rosetta and Damietta Branches which are equivalent respectively to the old Bolbitinic and Bucolic Branches (Fig. 12B). Concentration of discharge at Rosetta and Damietta locally changed the discharge/wave-power index, leading to a pattern of river-dominated sedimentation. The deltaic mud tended therefore: (1) to prograde further seaward across the shelf than in earlier times, and (2) to be more concentrated around the river mouths. Thus, before the closure of the Aswan High Dam (AHD), a substantial quantity of sediment was regularly brought down by the Nile to the Delta coast through the Rosetta and Damietta estuaries (Summerhayes & Marks 1976).

Quelennec & Kruk (1976) pointed out that 98% of the annual sediment load occurred during the flood season, with the following distribution:

July	August	September	October	November
2%	45%	38%	12%	1.5%

It was noted that 10 - 15 % of the annual suspended load was deposited in irrigation areas in Upper Egypt, and in the Nile bed upstream of Cairo. Not less than this amount, or may be more, should be presumably spread over agriculture lands of the Delta downstream of Cairo. Quelennec & Kruk (1976) pointed out, on the basis of comparison with known average rates of sedimentation at sea and with the volumes involved in some of the Nile Delta coastal changes, that the Nile load was deposited also outside the continental shelf before 1964.

The construction of the Aswan High Dam, combined with, more or less, complete damming of the river near Rosetta and Damietta, have turned the lower reaches of the Nile into tidal bodies of saline water. Cessation of sediment discharge means that the sands and prodeltic mud of the delta front are no longer being nourished by the river. The immediate effect will be a deepening of the sea bed in shallow water within a few kilometers of the Nile mouths. Deepening, in turn, will decrease wave attenuation, causing a gradual increase in the flux of wave energy at the coastline, thereby leading to a gradual increase in the rate of coastal erosion (Sumerhayes & Marks 1976).

AFTER CONSTRUCTION OF ASWAN HIGH DAM

The Nile flood usually carries a heavy load of mud - on the average 134 million tons annually (Aboul-Ata 1978). The Lake's area within the reach of this turbid water shows usually decreased transparency, varying through the years especially in the first decade of impoundment. In the early years of filling of the reservoir, for instance 1966, the turbid water reached as far north as the Aswan High Dam (Latif 1976a). In the following years, with the rise in water level, the range covered by turbid water receded southwards and it appears to be confined to the southern portion of the reservoir whereby this turbid water appeared only in Lake Nubia and southernmost part of Lake Nasser in the seventies. However, due to the low flood of 1972, the turbid water appeared only in Lake Nubia (Fig. 13).

In general the total load of suspended solids decreases from south to north due to the sedimentation of different components (sand, silt and clay), along the Nile's course as it moves across the reservoir. Sedimentological studies on Lake Nasser were carried out by many investigators (Entz 1974b, 1976 and 1980a, Philip *et al.* 1977, Aboul-Haggag 1977, Scott *et al.* 1978, Sherif *et al.* 1981, High Dam Authority 1982, El-Otify 1985, El-Dardir 1984 and 1987, Elewa *et al.* 1988, Sadiek 1987, El-Dardir *et al.* 1988 and Nour El-Din 1990).

Before the construction of the AHD the Nile used to discharge its sediments into the Mediterranean Sea. Since 1964, this amount of sediments has been held in the AHD reservoir. Hurst (1957) pointed out that about 100 million tons of suspended sediments (30, 40 and 30% fine sand, fine silt and clay) are carried annually with the Nile on entering Egypt. The quantity of these sediments increases greatly at the beginning of Nile flood. Elster & Vollenweider (1961) estimated the average value of suspended matter in the Nile at the Egyptian borders during the flood period (August to October), to 1.6

kg/m^3. However, after the construction of AHD and creating the High Dam Lake these features changed basically. According to Entz (1976) the amount of mud reaching Lake Nasser is about 0.1 kg/m^3/year. Entz (1980a) points out that the suspended material in Lake Nasser does not exceed a few milligrams per litre and it is mostly organic matter of planktonic origin. It seems that the center of sedimentation is located in the area of the pervious Second Cataract near Wadi Halfa, in which a new Delta started to grow. Thus, no clay reaches the Egyptian water, only with high turbidity in the southern region of the Lake. El-Otify (1985) and Habib *et al*. (1996) found that the total suspended matter fluctuated between a minimum of 10 mg/l and a maximum of 132 mg/l. A gradual increase in the total suspended matter was recorded along the main body of Lake Nasser from north to south in autumn and summer.

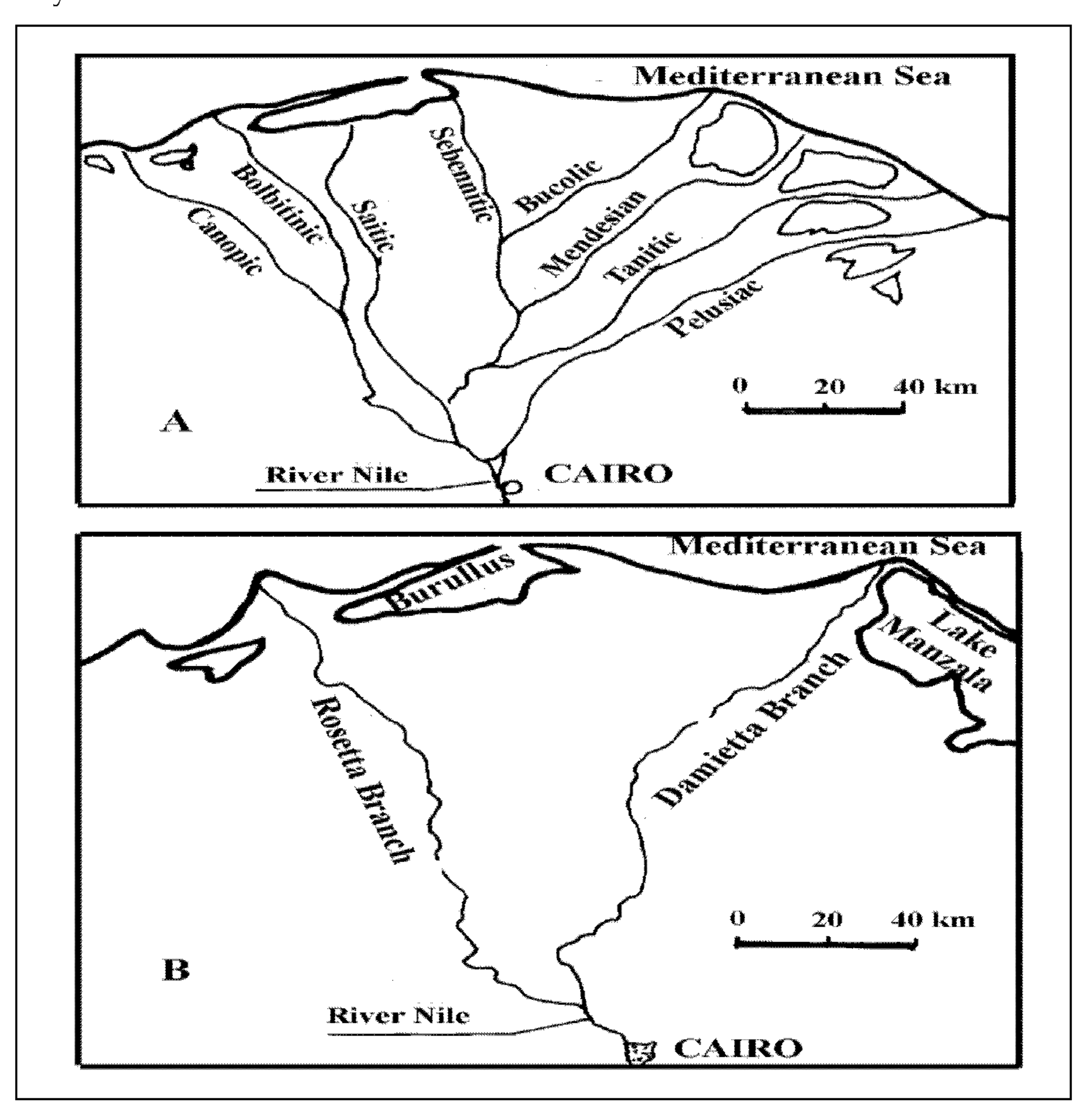


Fig. 12 A : Old Pharaonic branches of the Nile Delta.
B: Recent branches (Rosetta and Damietta) of the Nile Delta.
(Source: Latif, 1984a)

Rizkana & Aboul-Ezz (1964) pointed out that since the process of silting up of the reservoir will proceed year by year, the stored water reaching Egypt proper downstream of the Lake will be devoid of suspended material. This will also lead to a downvalley decrease in load relative to discharge with consequent increase in the erosive power of the water. Such change will decrease slope requirements of the down valley direction, thus preventing the Nile from attaining a slope of transportation or in other words a graded profile.

Aboul-Haggag (1977) showed that sedimentation in the High Dam Lake is controlled by many factors including the annual effective base level for each flood, the changes during hydrological year, the distribution and characteristics of rocky islands, the valley Lake bends, the old river terraces, the plankton induced deposition and certain man-made features. The maximum silt thickness (Fig. 14), that is, the area of most intense deposition, recorded in Lake Nubia until 1975 was at Gomi and the Second Cataract (Abca) where this layer was 17 and 20 m respectively, compared to 2 m at Adindan and 1 m at Abu-Simbel within Lake Nasser (Aboul-Haggag 1977).

Philip *et al.* (1977) describe most of the lake bottom sediments as clayey sediments. Scott *et al.* (1978) explain that the distribution of sedimentation in AHD reservoir is governed by the water level in the Lake, the volume of flood water and the distribution of the flood period at a given water level. El-Dardir (1984, 1987) reports that most of the sedimentation in the Lake takes place at the area north of El-Daweishat and south of Wadi Halfa in the Lake Nubia.

Entz (1980a) recorded the average rate of sedimentation as 90.480 million m^3 per year. The exact site and quantity of sedimentation depends on the total amount of sediments, its size distribution, velocity of water masses and the Lake water level. Sherif *et al.* (1981) studied the sedimentation processes in the High Dam Reservoir. They pointed out that the suspended silt load of the Nile flood (about 0.1 km^3 per year) was sedimented from 1968 to 1974 between Attiry (415 km south of the High Dam) and Abu Simbel (280 km south of the High Dam) and the bulk was deposited around the Second Cataract near Wadi Halfa. The latter authors pointed out that the suspended material in Lake Nasser did not exceed a few milligrams per litre and even that was mostly of planktonic origin. The High Dam Authority (1982) recorded a maximum sedimentation in the Lake between Amka and El-Daweishat 364 km and 431 km south of the High Dam respectively.

Estimates of the thickness of sediments, based on echosounding profiles and from the bottom level, have shown that the maximum sedimentation seems to occur in Lake Nubia (the Sudanese part of the reservoir) at Atteri, Murshid and Kingarti (400, 380 and 385 km from the High Dam respectively). The maximum sedimentation takes place at Adindan and Abu Simbel (in the southern part of the Egyptian sector of the reservoir) (El-Dardir 1984). The latter author concluded that undoubtedly, because of the sedimentation in the Lake, many of the channel islands and hills have been buried. Elewa and Latif (1988) reported that the

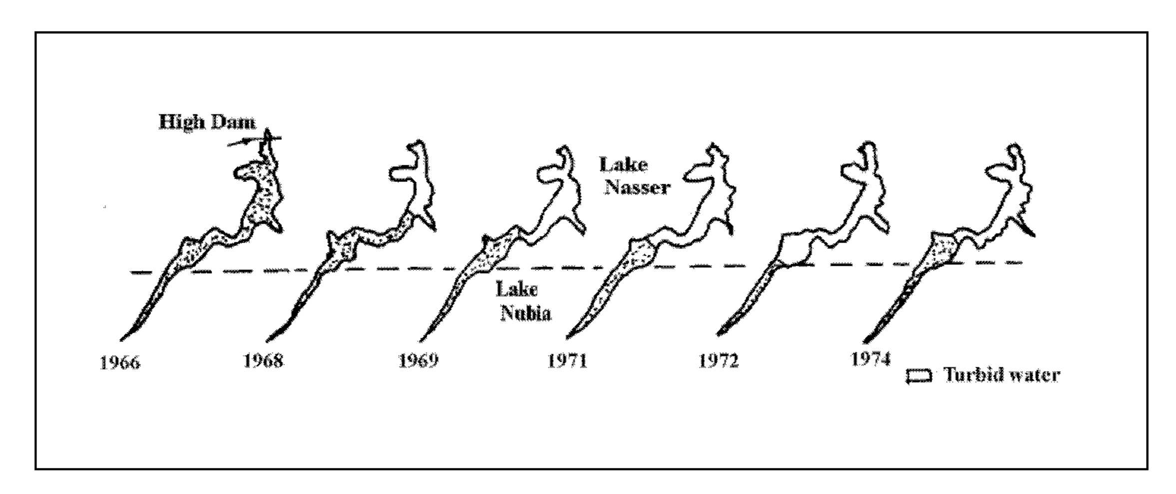


Fig. 13 **Extent of flood turbid water in some selected years (Latif 1984a).**

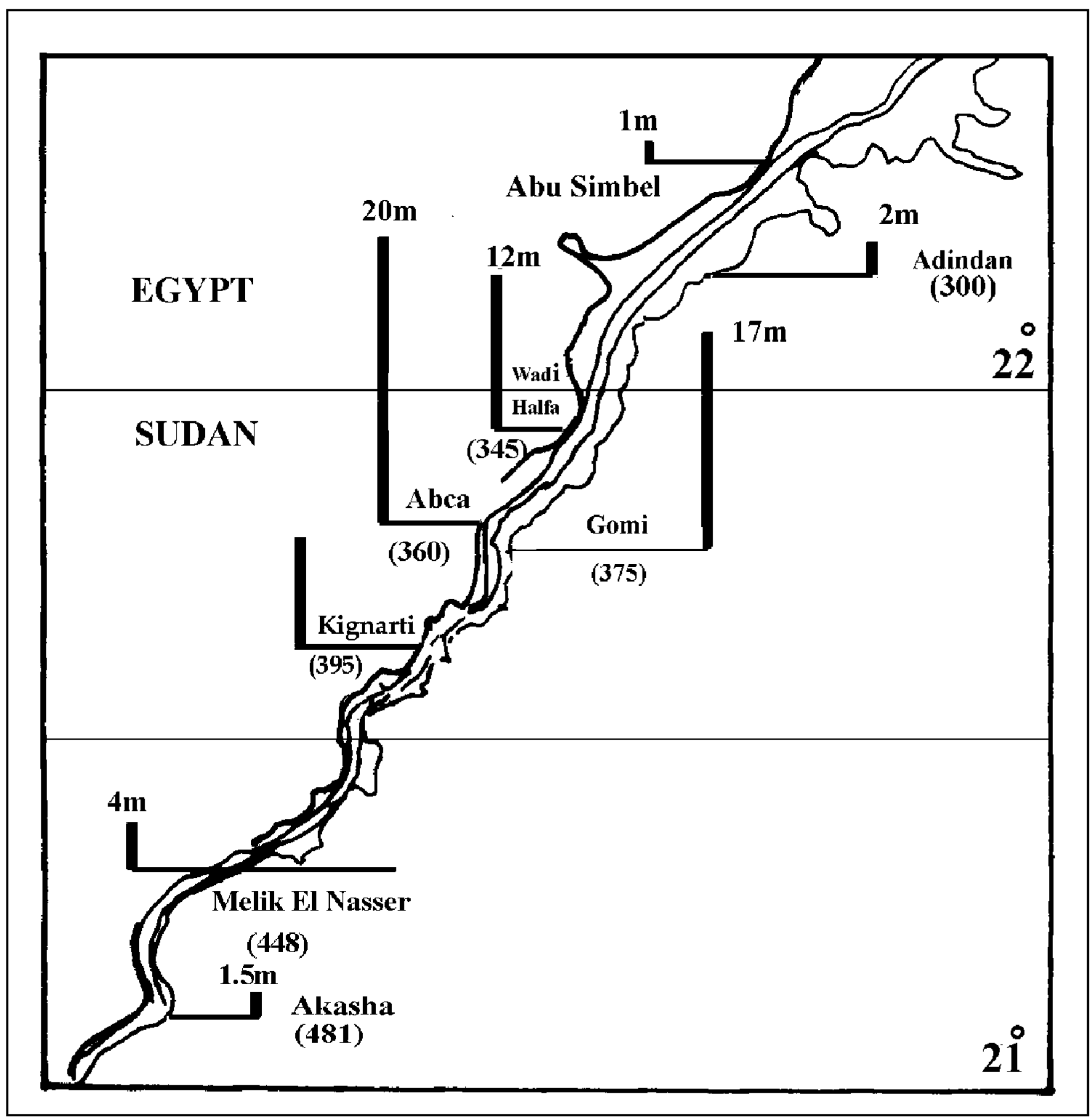


Fig. 14 **Distribution of siltation in the Aswan High Dam Reservoir. Figures in parentheses indicate distance (km) from the High Dam (Latif 1984a).**

bottom of the lake received its sediments mechanically from the flood and country rocks and chemically from solution, due to action of several physico-chemical parameters controlling the deposition of the chemical components. Sadiek (1987) showed that the lake sediments were deposited by tractive currents suspension load and tranquil water.

El-Dardir (1987) studied the sedimentation processes in Lake Nubia and concluded that the highest load value of suspended matter prevailed in the southern part and the lowest value in the northern region. This, in his opinion, goes parallel with the current speed, except at Kignarti and Gomi where this part is characterized by an abrupt increase in velocity. El-Dardir *et al.* (1988) report that the bottom sediments of the southern khors are composed of silt, clay and sand arranged in a decreasing order of abundance. Geochemical, minerological and sedimentological studies on some khors sediments of Lake Nasser were carried out by Gindy (1991).

Latif (1984a) pointed out that $30x10^9 m^3$ have been considered as dead storage, to account for the expected sedimentation during the expected 500 years life of the reservoir.

Nature of Sediments

The sediments were estimated to about 125 million tons/year, while other estimation of the total amount of sediment deposited since 1964 was about 1 km^3/year (Entz 1974b). The exact site and quantity of sedimentation depends on the total amount and its grain size distribution and the Lake level (Raheja 1970).

The darkest colour of sediment was observed near Aswan (Entz & Latif 1974). The latter authors related the dark grey colour to the relatively old sediments and the anoxic conditions during the summer stagnation period which lasts longest near the High Dam and has a decreasing duration towards the south. The light colour, on the other hand, was attributed to freshly sedimented silt with fairly low organic matter content.

Some microorganisms (Cladocera, Copepoda, ... etc.) behave as filtering organisms in the reservoir as they feed on finer materials suspended in the water. After digesting the organic content in the fine materials, these microorganisms coagulate the suspended particles to bigger droplets (Hafez 1977). These filtering organisms are believed by Entz (1974b) to be the main reason for the turbid water not reaching the northern section of the reservoir.

Deposition in Lake Nubia (Sudanese part) of the reservoir differs from that of the Egyptian part. At the entrance of Lake Nubia, where the Nile velocity and its related transporting power are decreased to the extent that the Nile becomes unable to hold the relatively large and heavy suspended materials, the river begins to put down its suspended load as sediment. So, the Nile is building up a new delta at the southern part of Lake Nubia by the

sedimentation of the relatively heavier and coarser parts of the material in suspension while the finer fractions settle down further north in the Egyptian part of the reservoir.

The environmental conditions such as, parent material, chemical composition, pH, Eh (electromotive force), temperature and water circulation are the controlling factors affecting the formation of clay minerals (Degens, *et al.* 1957).

Effect of Environmental Factors on Nature of Sediments

Higazy *et al.* (1986) studied the environmental influence on the clay mineral formation and deposition in the High Dam Reservoir and concluded the following:

The clay deposit in the reservoir is detrital and authigenic, but the authigenic clay minerals reflect the chemistry of the environment more closely. It is believed that these clay minerals are mainly authigenic due to the abundance of montmorillonite. Chemical and physical properties of elements control their deposition. The pH values of the bottom sediment, as well as, the pH values of the overlying water are in harmony with the montmorillonite/kaolinite (M/R). Also, the seasonal variation in temperature of the water controls the thermal stratification of this water and hence affects its oxygenation which is responsible for the oxidation-reduction conditions, as well as, the life of plants, animals and organisms that affect the rate of deposition. Since slight acidic media favour the formation of kaolinite, while slightly basic media favour the formation of montmorillonite, the X-ray analysis data show that kaolinite is inversely proportional to montmorillonite for compensation between pH and Eh. Heavier and coarser parts of the suspended materials are deposited in the Sudanese part of the reservoir (Lake Nubia) especially at its entrance, while the final fraction settles down in the Egyptian part of the Aswan High Dam Reservoir. The spatial variation in the reservoir sediment indicates that the water is slightly more basic upstream, while the spatial variation in the trace elements of the clay fractions shows that manganese increases southwards, while magnesium displays maximum decrease at Allaqi and reaches maximum increase at Adindan. Generally, the spatial variation of the trace elements in the clay fraction is conformable with the spatial variation of the pH.

Elewa & Latif (1988) investigated the effect of physico-chemical conditions on the deposition of some elements of Aswan High Dam Reservoir water and concluded the following:

1. The water of the reservoir may be divided into two media:
   a- Oxidized (the oxygenated layer) alkaline layer.
   b- Reduced with free H_2S, slightly alkaline layer (the non-oxygenated layer).
2. Temperature, oxidizable organic matter and free oxygen play an important role to form the two media.
3. Deposition of the carbonate is related partly, to the alkaline medium,

however, the carbonate secreting or encrusting organisms play the major role at some parts of the reservoir.

4. Al_2O_3 and Fe_2O_3 are deposited simultaneously as hydrolysates, however, the distribution of Na_2O and K_2O favours the presence of sodic and potash feldspars.
5. Iron, manganese and heavy metals were deposited in the form of colloidal sulphides in the reduced, slightly alkaline medium.
6. Copper and zinc were deposited adsorbed onto the colloidal manganese.

Mechanical Analysis of Sediments

Fishar (1995) studied the bottom sediments of Lake Nasser during 1993 at 10 stations (Fig. 15 and Table 11), his results are presented in Table 12.The latter author showed that the bottom sediments of the Lake are heterogeneous, and in the main channel they are mainly silty clay and clayey silt, while the samples representing the eastern and western sides include more sand. The highest percentage of mud (silt and clay) was recorded in the main channel of the southern stations (Tushka, Abu Simbel and Adindan), while the western side of Singari and Abu Simbel sections have established muddy sandy bottom (Fishar 1995 - Table 12).

Relation between sediment, calcium carbonate, organic matter and productivity

Latif *et al.* (1989) determined the calcium carbonate and organic matter in the bottom sediments of the northern, middle and southern sectors of Lake Nasser, and their effects on the productivity of the Lake (Table 13). The highest values of $CaCO_3$ were recorded at Amada (middle area) (9.99 - 11.27%) compared with 1.71 - 2.61% and 2.81 - 3.37% at Adindan and El-Birba respectively. Plants and planktonic algae are well known for their ability to extract CO_2, raise pH and thus promote precipitation of carbonate. Phytoplankton production can be a major factor in the precipitation of calcium carbonate.

The highest productivity is recorded in the middle area of the Lake (Table 13). A significant correlation between calcium carbonate concentration in the bottom sediments with the productivity of the Lake (Table 13) is observed. Fishar (1995) calculated the percentage of organic matter in the bottom sediments of Lake Nasser and found that it ranged from 0.93% in the western station of Adindan section to 2.99% in the main channel of Maryia section. Fig. 16 clearly shows a seasonal pattern of organic matter in Lake Nasser. The highest percentages of organic matter were recorded during winter, with average values of 1.91, 2.67 and 2.36% in the eastern side, main channel and western side respectively. This was followed by a decrease in the value at the two sides during spring. In summer, a slight increase in the percentage of organic matter was observed in the main channel attaining 1.93%, in contrast to another decrease at both sides reducing the values to be 1.18 and 1.43% in the eastern and western sides respectively. In autumn, an increase in percentage of organic matter was recorded in the eastern side and main channel, while a decrease in percentage was observed in the western side to attain an average value of 1.03%.

Table 11 **Latitudes, longitudes and distance from the High Dam (km) of selected sections in Lake Nasser during 1993 (Fishar 1995).**

Site	Latitudes		Longitudes		Distance from the HD
Upstream	23°	56.24´	32°	51.89´	29
Dihmit	23°	51.1´	32°	53.78´	21
Kalabsha	23°	33.41´	32°	52.04´	47.7
Mariya	23°	20.08´	32°	56.12´	74.3
El-Madiq	22°	6.47´	32°	37.68´	130.1
Singari	22°	37.65´	32°	24.14´	167.2
Amada	22°	43.97´	32°	5.45´	199.
Tushka	22°	36.32´	31°	55.21´	240.
Abu Simbel	22°	19.71´	31°	37.14´	268.8
Adindan	22°	14.71´	31°	31.81´	299.7

Table 12 **Calculated percentages of sand, silt and clay fractions at different localities of Lake Nasser during 1993 (Fishar 1995).**

Site	Locality	Sand (%)	Silt (%)	Clay (%)	Type of sediments
	E	20	41	39	sandy muddy
Upstream	M	5	22	73	black mud
	W	29	39	32	sandy
	E	3	56	41	muddy
Dihmit	M	7	26	67	black mud
	W	15	33	52	sandy mud
	E	16	51	33	sandy muddy
Kalabsha	M	4	26	70	black mud
	W	9	47	44	sandy muddy
	E	22.1	39	38.9	sandy muddy
Maryia	M	3.8	33	63.2	black mud
	W	28	22.5	49.5	muddy sand
	E	36	41	21	muddy
El-Madiq	M	2.4	30.1	67.5	black mud
	W	34	41	25	muddy sand
	E	7	70	23	muddy
Singari	M	7.8	22	70.2	black mud
	W	62	22	16	sandy
	E	40	31	29	muddy sand
Amada	M	5.1	67	27.7	black mud
	W	43	29	28	muddy sand
	E	30	29	41	sandy mud
Tushka	M	2	66	32	black mud
	W	42	17	41	muddy sandy
	E	12	30	58	sandy mud
Abu Simbel	M	2	26	72	black mud
	W	62	17	21	muddy sand
	E	33	46	21	sandy muddy
Adindan	M	1.9	32.1	66	black mud
	W	37	46	17	sandy muddy

E: Eastern side; M: Main channel; W: Western side [For stations refer to Fig. 15 and Table 11].

Table 13 **Relation between sediment, calcium carbonate, organic matter and productivity in Lake Nasser during 1981 – 1983 (Latif *et al.* 1989).**

	Spring			Summer			Autumn			Winter		
	El-Birba	Amada	Adindan	El-Birba	Amada	Adindan	El-Birba	Amada	Adindan	El-Birba	Amada	Adindan
$CaCO_3$ (%)	2.81	11.26	2.22	3.28	11.27	2.61	2.97	9.99	2.23	3.37	10.44	1.71
Organic matter (%)	2.23	2.22	1.96	3.11	2.68	2.85	3.62	3.39	3.03	2.36	2.18	2.87
Chlorophyll *a* concentration (μg/l)	3.8	11.7	2.8	0.95	6.1	3.5	4.7	6.7	3.3	5.5	11.1	2.0
Zooplankton biomass (g/m^3)	6.1	13.3	16.4	1.5	5.9	8.3	4.1	9.7	11.8	3.2	4.8	5.5
Benthos biomass (g/m^2)	139.5	44.0	13.2	25.2	13.8	16.1	1.0	2.1	9.7	3.5	6.0	5.6

Habib *et al.* (1996) pointed out that the levels of particulate organic matter in the northern region of Lake Nasser (stns. 1 - 3) were comparatively low as compared with the southern region. The average amount of particulate organic matter ranged from 0.4 to 7.5 g/m^3. Similar seasonal patterns were observed with the maximum in July - September and minimum in December - February at the southern stations (4 - 6). Peaks of particulate organic matter appeared a little earlier at the northern stations (April-July) than at the southern stations (July-August). The seasonal patterns of particulate organic matter (Fig. 17) were similar to those of suspended solids (Fig. 18) at station 6.

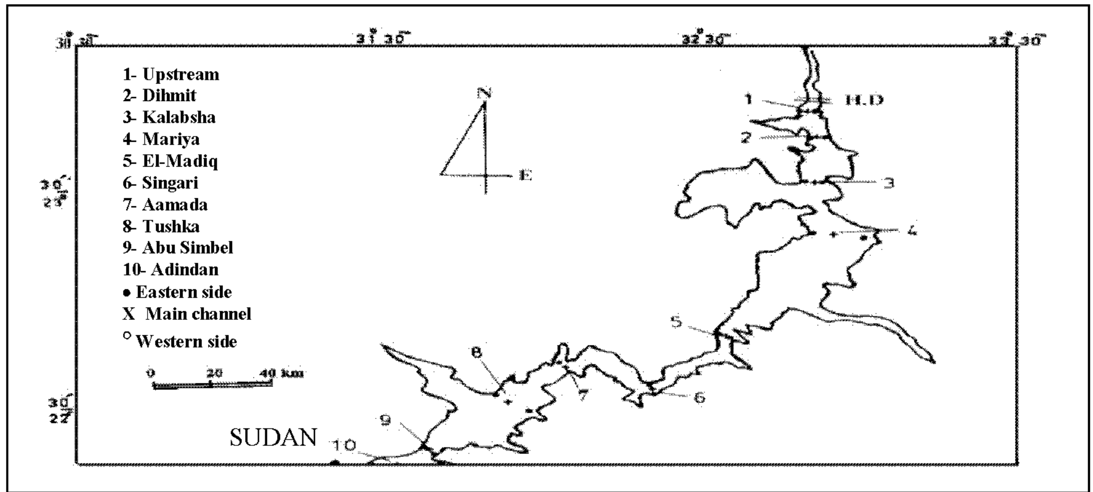


Fig. 15 **Map of Lake Nasser (at 180 m level) showing location of stations. (Fishar 1995).**

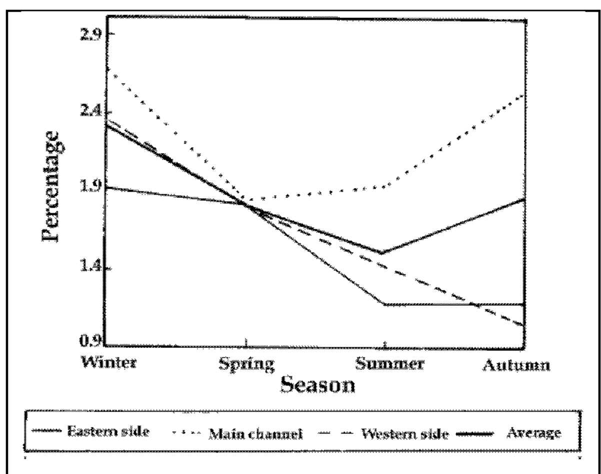


Fig. 16 **Seasonal variations of percentage of total organic matter in the sediment of Lake Nasser (Fishar 1995).**

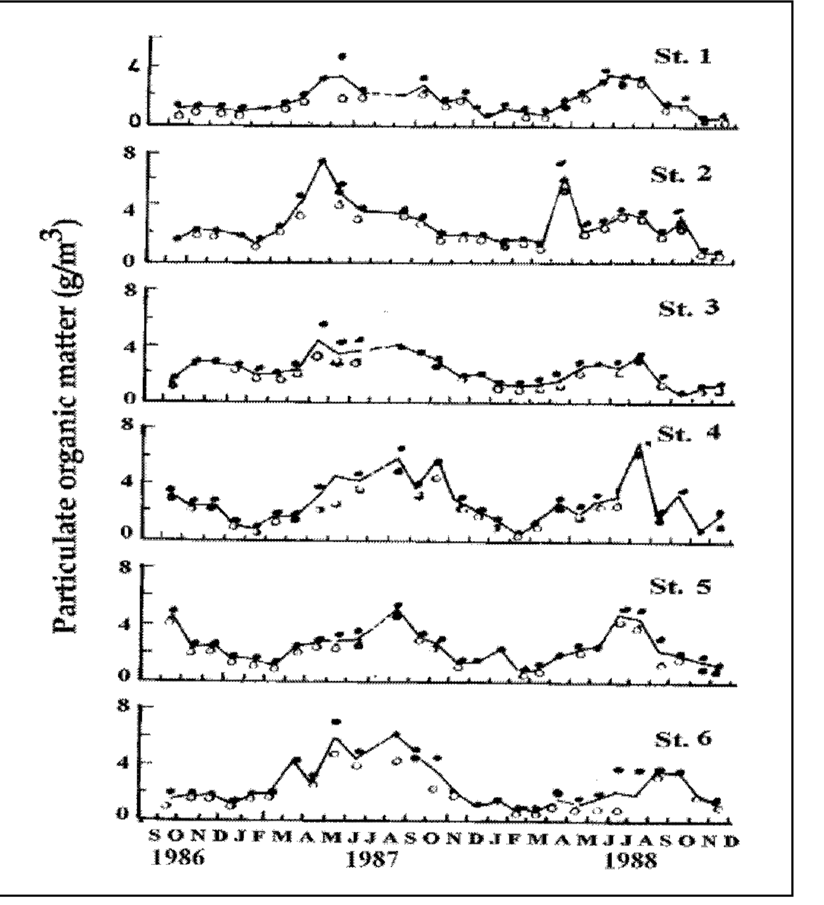


Fig. 17 **Seasonal changes of the particulate organic matter at stns. 1-6 in the main channel of Lake Nasser. Lines are for averages of the surface (◦) and 2m (•) samples (Habib *et al.*1996)** [For stations refer to Fig. 4].

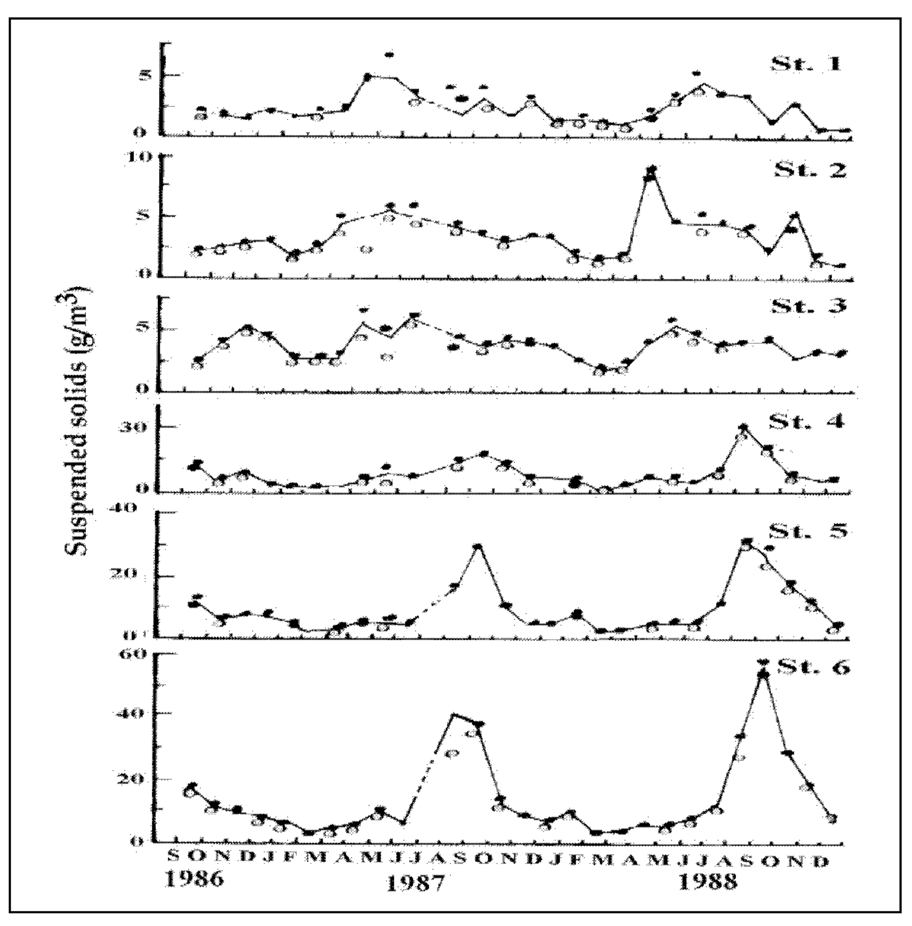


Fig. 18 **Seasonal changes of the suspended solids at stns. 1-6 in the main channel of Lake Nasser. Lines are for averages of the surface (◦) and 2m (•) samples. (Habib *et al.* 1996).**

Heavy Metal Concentrations in Relation to Lake Sediments

Pathways and distribution of metals in natural waters are necessary for assessing the current status of metals in the environment and for avoiding potential problems due to metals. Sediments and suspended particulate matter play an important role in the dynamics of organic and inorganic compounds in the aquatic environments (Felz 1980, Wakehom & Farrington 1980). Highly charged clay particles are responsible for the proportion of both cations and anions (Grobler *et al.* 1981). The organic matter associated with sediment particles is largely responsible for the ability of sediment to adsorb uncharged organic compounds (Karickhoff 1983). Therefore, pollutant concentrations in sediments usually increase with decreasing particle size (Dossis & Warren 1980). Elewa *et al.* (1990) assessed the levels of iron, manganese, copper and zinc in the surface sediment of Lake Nasser in summer and winter 1988 (Figs. 19-22). The results indicate that in Lake Nasser, copper content is high (56 - 81 ppm) as compared with that of Lake Nubia (38.3 - 42.9 ppm). There is a consistent correlation between copper content and depth of the collected samples, as well as the grain size and and organic matter contents (Glenn & Van Atta 1973, Schettle & Friedmann 1973).

In Lake Nasser, zinc content ranges between 77 - 432 ppm. Generally, zinc concentration in Lake Nasser increases rapidly southwards to reach its maximum value of 432 ppm at Abu Simbel, followed by an abrupt decrease to 166 ppm at Adindan, and further decrease to 63.1 ppm in the most southern region in Lake Nubia. Furthermore, the enrichment of zinc in Lake sediments in the area lying between Singari and Abu Simbel (Fig. 20) is associated with its accumulation with organic matter (Elewa 1980). In the sediments of Lake Nasser, Cu and Zn distribution is more related to the amount of clay. Meanwhile, Zn and Cu are chiefly adsorbed onto the clay minerals and hydrated iron and manganese oxides (El-Dardir 1984). On the other hand, the accumulation of Zn and Cu in the sediment may be the result of the deposition of metal rich planktonic debris and subsequent degradation of the debris (Takamatsu *et al.* 1985).

Robbins & Callender (1975) and Forstnar (1983) point out that the cycling of Mn within sediments is well known to vary with the redox condition of the sediment. Thus, Mn is precipitated primarily within inorganic and organic particles on the Lake bottom. Takamatsu *et al.* (1985) have shown that Mn concentration was very high in the oxidized uppermost layer of offshore sediment. This may result from the dissolution-deposition cycles of Mn within the water sediment interface of Lake Nasser (Elewa *et al.* 1990). The trend of Fe distribution in Lake Nasser was low in the northern region followed by an increase southward (Fig. 22).

Lake Nasser is a productive Lake with clinograde oxygen-curves, with the oxygen deficient part in the hypolimnion during the warm period in summer and early autumn. Fe and Mn are liberated from sediments as sulphides. Thus, several mechanisms are responsible for the remobilization of these metals e.g. desorption, dissolution, mineralization, ligend exchange and enzymatic hydrolysis. These processes are affected by environmental factors such as: redox potential, pH, temperature, turbulence and depend on the dynamic equilibrium between the

concentrations of metals in the interstitial water and the sediment (Bostrom *et al.* 1982, Elewa 1976 , Grobler *et al.* 1987).

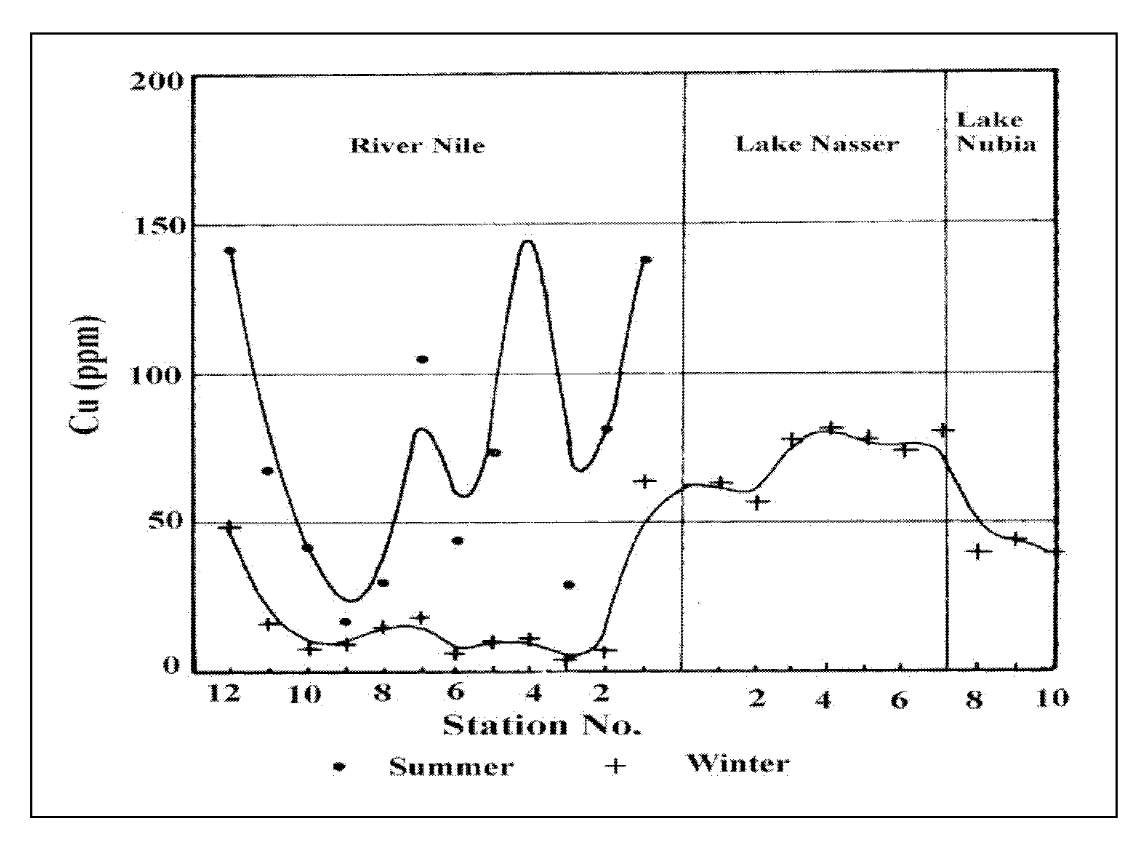


Fig. 19 **Copper distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

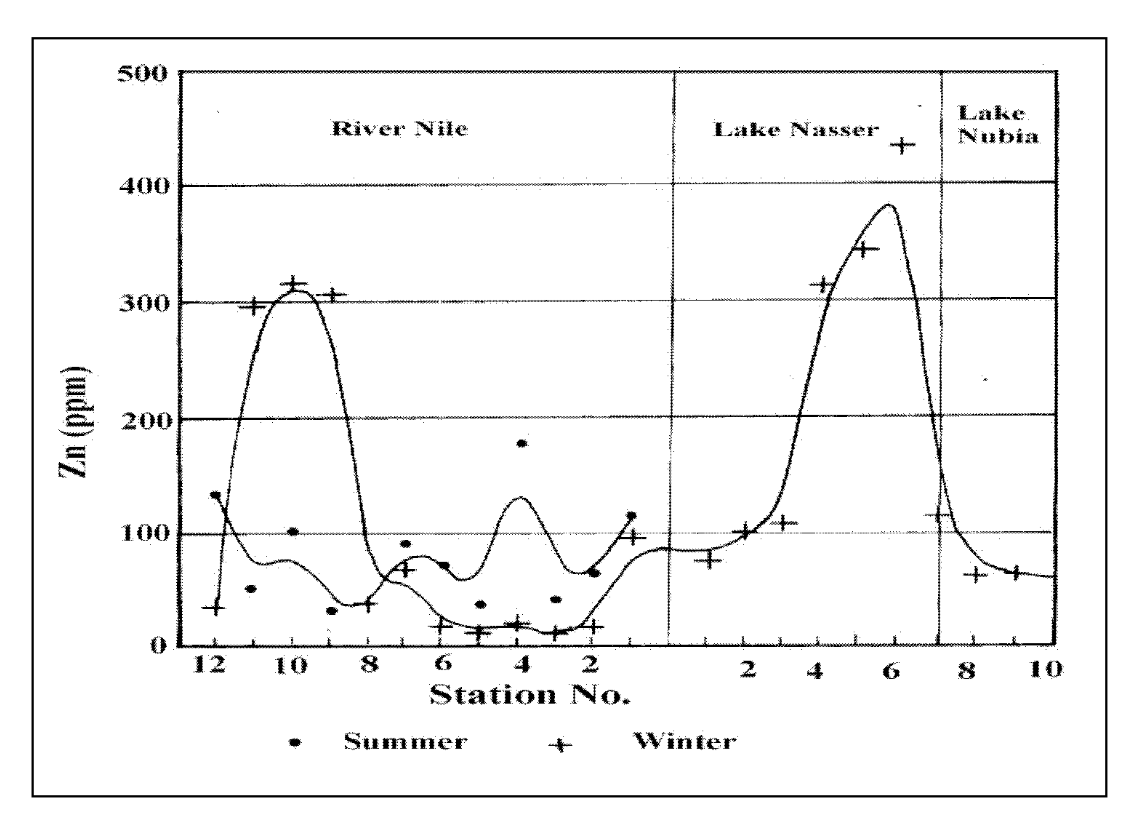


Fig. 20 **Zinc distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

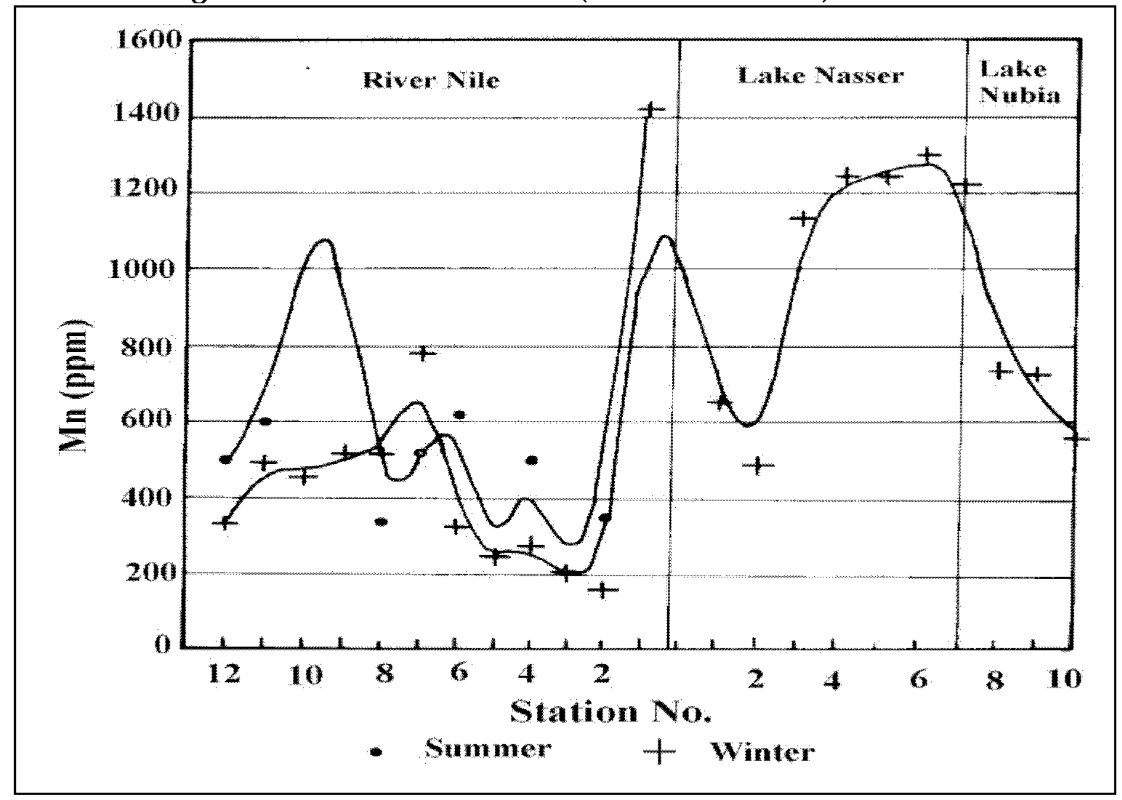


Fig. 21 **Manganese distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

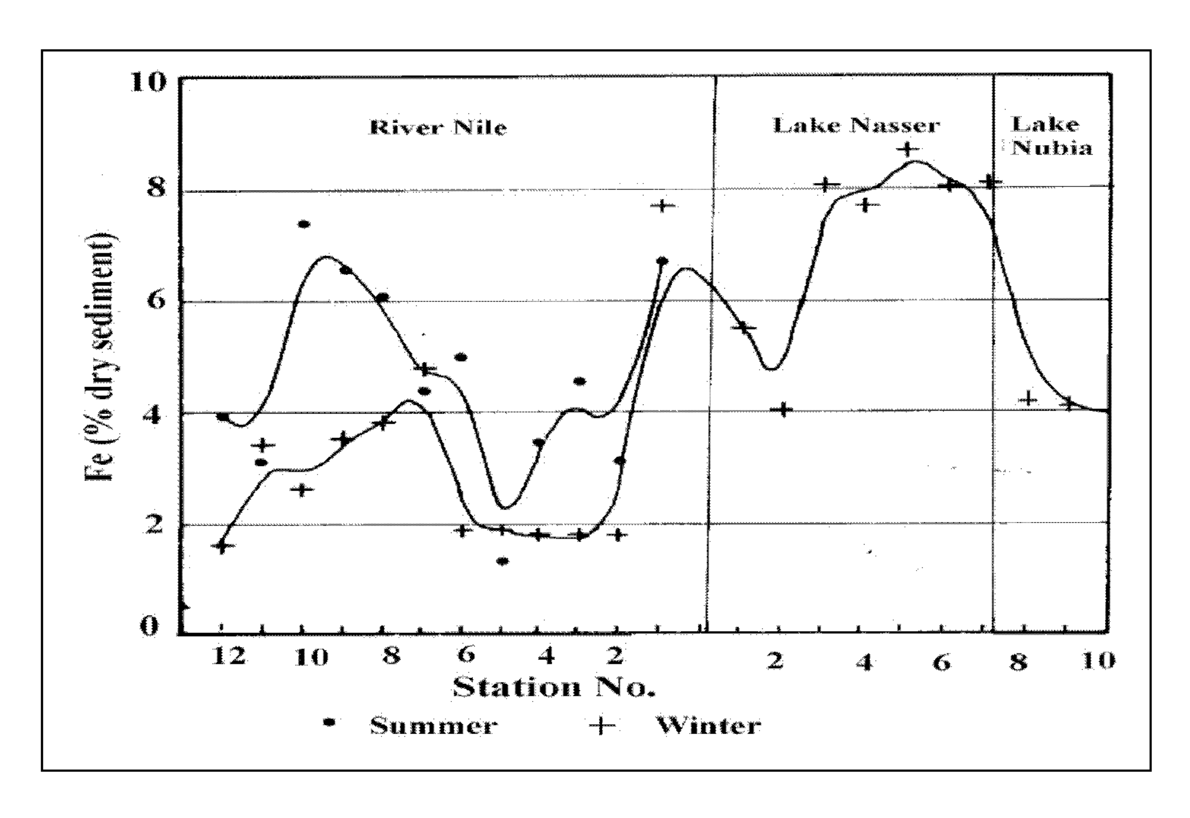


Fig. 22 **Iron distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

Alsterberg (1927) and Hutchinson (1957) report the direction of transpiration of elements from sediments into free water being controlled by temperature and oxygen stratification and by the morphology of the Lake basin. In turn, the presence or absence of the oxidized microzone in the bottom sediment constitutes an immense difference to the amount and nature of substances leaving the mud and passing into the water (Gorham 1965). Elewa *et al.* (1990) mentioned that, the enrichment of a given element in Lake Nasser sediment may be affected by a variety of environmental factors. Few elements are more concentrated into the organic mud, e.g. Fe and Mn . Another factor affecting Fe distribution is the grain size. Krauskopf (1956) indicates that the depletion of Cu and Zn could be the result of precipitation as sulphides. On the other hand, the role of redox chemistry in controlling the distribution of Fe and Mn can be observed in the sediment of Lake Nasser (Elewa *et al.* 1990). The latter authors conclude that Fe, Mn, Zn and Cu are concentrated in the clay sediment rather in the silt and sand. On the other hand there is a positive correlation between these metals and the organic matter content. It is concluded that Lake Nasser sediments are more concentrated with these metals in comparison with downstream River Nile.

CONCLUSIONS

Before AHD construction an average of about 124 million tons of mud was brought annually with the flood, 10 - 15% was deposited in irrigation areas of Upper Egypt and in the Nile bed upstream Cairo. About the same amount or more was spread on agricultural land of the delta, in addition to paramount quantity brought down to the Delta coast through the Rosetta and Damietta estuaries, in addition to deposition outside the continental shelf.

After the construction of AHD and complete filling of Lake Nasser the amount of mud reaching the Lake is about 0.1 - 10 mg/l, and recently 10 - 132 mg/l (average 0.1 km^3/year) of suspended material mostly organic matter of planktonic origin. After damming the river near Rosetta and Damietta, the lower reaches of the river turned into tidal bodies of saline water. A gradual decrease of suspended matter was recorded from south to north of the Lake. Until 1977 the center of sedimentation was located in the area of Gomi and Second Cataract near Wadi Halfa where a layer of 17 - 20 m thickness was deposited compared to 2 and 1 m at Adindan and Abu Simbel within Lake Nasser where maximum sedimentation occurs. Dead storage has been estimated as $30x10^9m^3$, to account for the expected sedimentation during the expected 500 years life of the reservoir.

There are many physico-chemical conditions affecting deposition of elements in the reservoir including: media of reservoir (oxidized or reduced),

temperature, deposition of carbonate, Al_2O_3, Fe_2O, Na_2O, K_2O as well as heavy metals (Fe, Mn, Cu, Zn etc.). The bottom deposits of the reservoir are heterogenous mainly silty clay and clayey silt in the main channel containing more sand on the sides of the Lake.

There is a relationship among calcium carbonate, organic matter and productivity. The highest $CaCO_3$ content of the sediment was recorded at Amada (middle area) with the highest productivity, as phytoplankton can be a major factor in $CaCO_3$ precipitation. The seasonal pattern of organic matter in the Lake shows the highest values in winter in the main channel and both sides of the Lake followed by a decrease coinciding with the fluctuation of phytoplankton being highest in winter.

The particulate organic matter is higher in the southern region compared with that in the northern region. The southern region is richer in both phyto- and zooplankton compared with the northern region. The seasonal pattern of particulate organic matter is similar to that of suspended solids at the southernmost stations. Maximum particulate organic matter is recorded in summer.

Regarding heavy metals in the sediment in Lake Nasser, they are more concentrated in the Lake than downstream the Nile. Copper concentration in Lake Nasser is higher than in Lake Nubia. There is a consistent correlation between copper content, depth, grain size and organic content. Zinc concentration ranges between 77 - 432 ppm showing an increase southwards to reach its maximum at Abu Simbel, followed by an abrupt decrease to 166 ppm at Adindan, and further decrease (63.1 ppm) in the southernmost region of the Lake. Enrichment of zinc in Lake sediment between Singari and Abu Simbel is associated with its accumulation with organic matter. Zn and Cu are merely adsorbed onto the clay minerals and hydrated iron and manganese oxides. Accumulation of Zn and Cu in sediment may be the result of the deposition of metal rich planktonic debris and subsequent degradation of debris.

Manganese concentration is very high in the oxidized uppermost layer of offshore sediment which may result from dissolution, deposition cycles of manganese with the water sediment interface in the lake.

Iron is low in the northern region followed by an increase southwards. In summer stagnation Fe and Mn are liberated from the sediment as sulphides. This process is affected by many factors as redox potential, pH, turbulence, temperature and dynamic equilibria between metal concentrations in the interstitial water and the sediment. Thus several mechanisms are responsible for the remobilization of these metals, i.e. hydrolysis, dissolution, mineralization, ligend exchange and enzymatic hydrolysis. Furthermore the presence or absence of the oxidized microzone in the bottom sediment constitutes an immense difference in the amount and nature of substances

leaving the mud and passing onto the water. Grain size is another factor in distribution of iron, the rate of redox chemistry seems to play a role in controlling distribution of Fe and Cu in the Lake. It seems that Fe, Mn, Zn and Cu are concentrated in the clay sediment rather than in the silt and sand.

Chapter 3
Physical Environment

It is essential to understand the abiotic environment in Lake Nasser and its relation with biological processes. Physical factors affect, directly and indirectly, the various organisms inhabiting the Lake. Fish migration may be controlled by water temperature and currents. Primary production is also affected by transparency. Increase or decline of tilapia production, forming more than 90% of the total Lake fish production, due to changes in the area of spawning grounds, is related to changes in water level, shoreline length and other factors. Physical processes such as lateral and vertical movements of water masses, diffusion from water surface or bottom sediments, inflowing of a highly turbid water mass, and stratification of the water column cause changes in the distribution and concentration of many kinds of chemical substances. The changes in chemical aspects caused by these physical processes may affect the biological processes in the Lake. Therefore, the physical and chemical aspects are closely related with the biological activities in the Lake ecosystem.

Since the completion of the High Dam, many investigators (Entz & Ramzy 1971, Entz 1972, 1974b, 1976, Entz & Latif 1973, 1974, El-Shahawy 1975, Elewa 1976, 1980, Latif & Elewa 1977, 1980, Fead 1980, Latif 1984a, Ahmad 1988, Ahmad *et al.* 1989, Abdel-Monem 1995, Abdel-Mageed 1995, Fishar 1995, SECSF 1996, Mohamed 1998 etc.) studied the various parameters of the Lake environment. Nevertheless, it is unknown up to the present whether the various aspects of the Lake ecosystem have reached a steady state or not. Hence, a clear situation and trend of long-term changes of abiological environment and its relation with biological activities in the Lake is greatly needed at present and continuous monitoring of the various parameters is of utmost importance.

Investigating physical and chemical characteristics of Lake Nasser, provide data which can be used for the following purposes:

1. To know the effect of the abiological environment on the biological processes of aquatic fauna and flora and total ecosystem in the Lake.
2. To clarify the relation between abiological environmental changes and aquatic resources especially fish.

3.To achieve the stabilization of fish resources for the permanent maintenance, proper management and development of fisheries, using scientific knowledge on the Lake environment (sustainable development).
4.To use the obtained scientific knowledge for improving the fishermen's welfare and prosperity.

Needless to mention that with the formation of Lake Nasser, the impounded water changed from riverine to lacustrine conditions. The main factors affecting the physico-chemical properties in the Lake are temperature and flood.

TEMPERATURE

Water Temperature. The average values of air temperatures recorded in Lake Nasser are 33.1, 40.4, 36.0, and 25.7 °C compared with 25.8, 28.6, 25.7 and 16.7 °C for surface water in April, July, October and January respectively (Fig. 23). It is worth mentioning that the difference between surface and bottom temperatures in riverine environments, is found to be slight, while the difference increases with impoundment, becoming more pronounced in summer.

In Lake Nasser, because of the low relative humidity (the Lake is surrounded entirely by desert), especially in summer when humidity falls below 20 or 30% evaporation must be very great. This phenomenon may explain why the mean water temperature at the surface of the Lake in the summer is about 5 - 7 °C much lower than the mean air temperature. In general, there seems to be a close correlation among air temperature, humidity, mean strength and duration of wind, and surface water temperature.

Comparing Lake Nasser with Lake Volta, air and water temperatures in the latter were almost the same all around the year, but water temperatures were normally a little higher than air temperatures, because of the high humidity and low rate of evaporation.

Surface Water Temperature and Regional Variations. Studies during 1983 on monthly variations of water temperature in the main channel of the Lake show that the monthly average values range from 18.5 °C in February to 26.6 °C in September (Table 14). A relatively high value (i.e. 25.3 °C) is recorded in July, being affected by the high air temperature during this month. The mean annual water temperature recorded at different stations show slight regional variations, with a difference of 1.7 °C between the minimum of 20.2°C at stn. 1 (El Ramla) and the maximum of 21.9 °C at stn. 3 (Allaqi) (Table 14). The mean annual value at six stations in the Lake is 21.2 °C. It is worth mentioning that during warm and cold seasons surface water temperatures are not far from those of the air. Records of 1996 (SECSF, 1996) of the surface water temperatures show that the minimum temperature is recorded at the High Dam site in winter (16.28 °C) and the maximum (34 °C) at Tushka (Table 15) in summer. In 1993/1994 the average water temperature at all stations along the main channel varies from a minimum of 20.21

and 20.51 in spring and winter to a maximum of 29.2 °C in summer (Abdel-Mageed 1995).

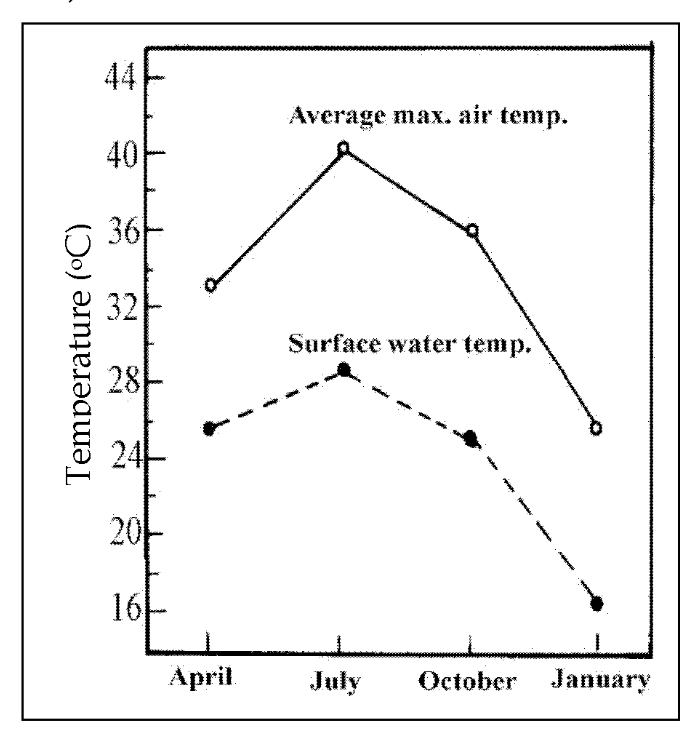


***Fig.* 23 Relation between surface water temperature and average maximum air temperature in different seasons (Latif 1984a).**

Thermal Stratification. The changing conditions of Lake Nasser result in the occurrence of thermal stratification in summer. This phenomenon could be followed from the early data during the period 1973 - 1979 (Elewa 1980). The latter author summarized the seasonal features of the water column in the following:

a. No thermal stratification was observed during winter, as the water temperature shows no or slight difference with depth (Table 16 and Fig. 24).

b. A decrease in water temperature with depth becomes clear in spring. In May the water temperature difference was wider than in April (Fig. 25).

c. During summer, Lake Nasser is stratified and the surface water temperature reaches its maximum. Generally, the temperature difference between surface and bottom waters shows a wide range in summer (Table 17 and Fig. 26).

d. In autumn, the picture is different in the northern region of the Lake than at the southern one (Table 16 and Fig. 27).

Elewa (1987a) shows that the thermal stratification becomes more prominent during summer time, with wide difference in temperature between the surface and bottom. He adds that the destruction of stratification takes place in autumn and winter due to the lowering of air temperature and intrusion of flood water in the southern part of the Lake.

Latif (1984a) mentioned that during 1970, 1974, 1975 and 1976, the maximum surface water temperature was 31.4 °C in September 1975 at Allaqi, and the minimum 15 °C prevailed at Adindan in January 1975. The minimal bottom temperature of 15 °C was also recorded in January 1975 and the highest bottom temperature of 24 °C in November 1974.

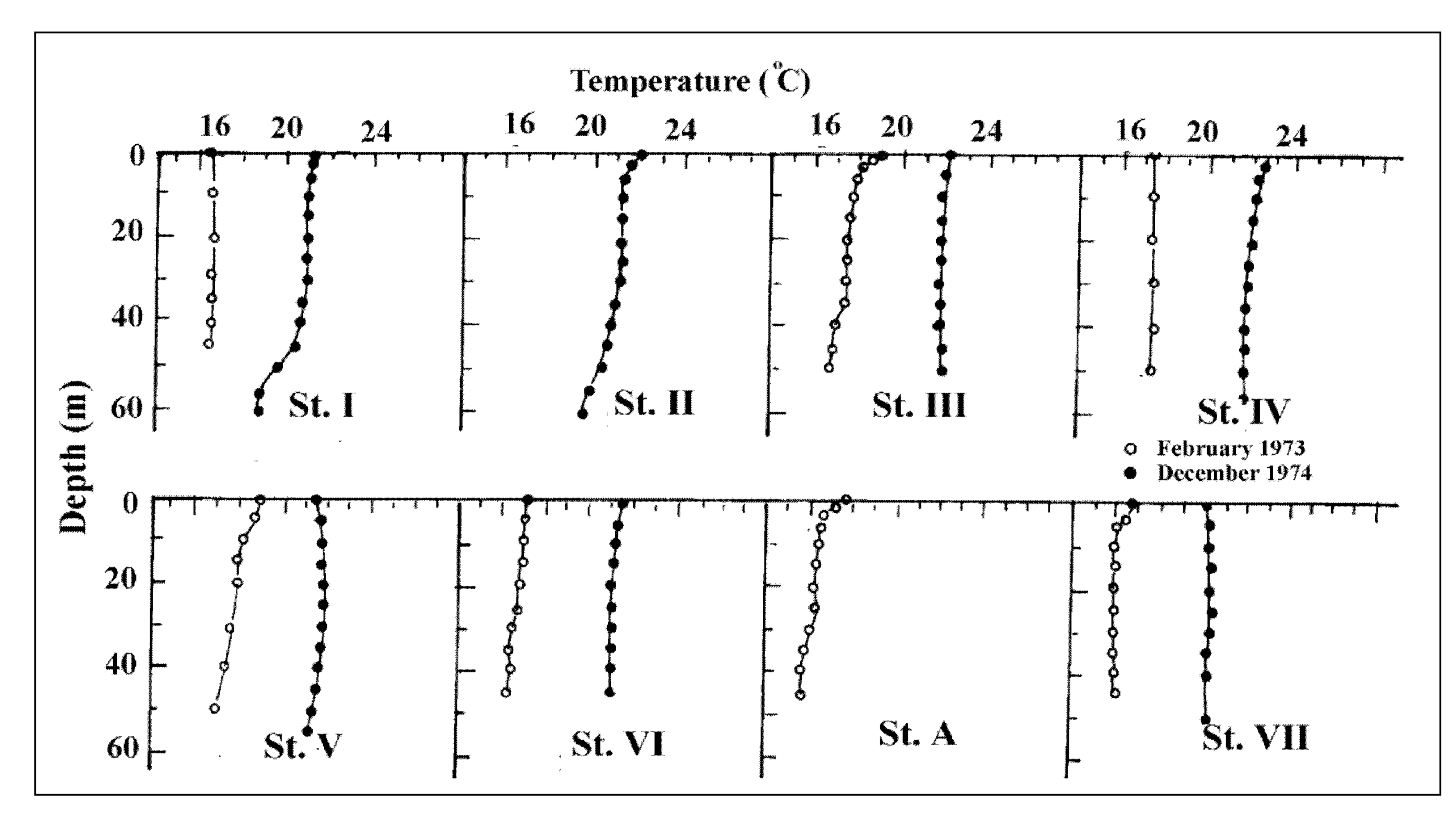


Fig. 24 **Temperature profiles of lake Nasser in different stations during winter 1973/ 1974, (Elewa 1980) [**For stations refer to Table 18, main channel**].**

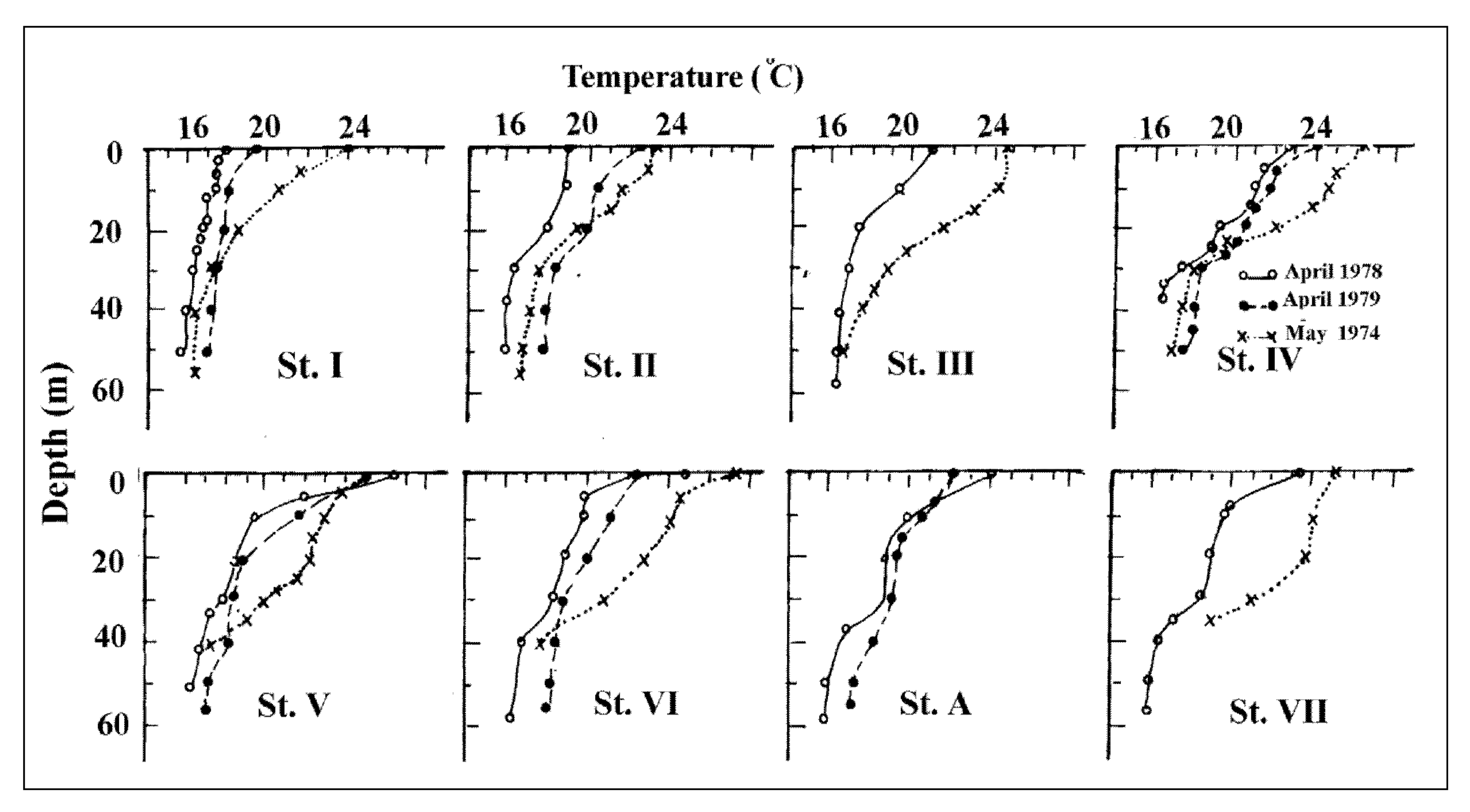


Fig. 25 **Temperature profiles of lake Nasser in different stations during May 1974, April 1978 and April 1979 (Elewa 1980)**

[For stations refer to Table 18, main channel].

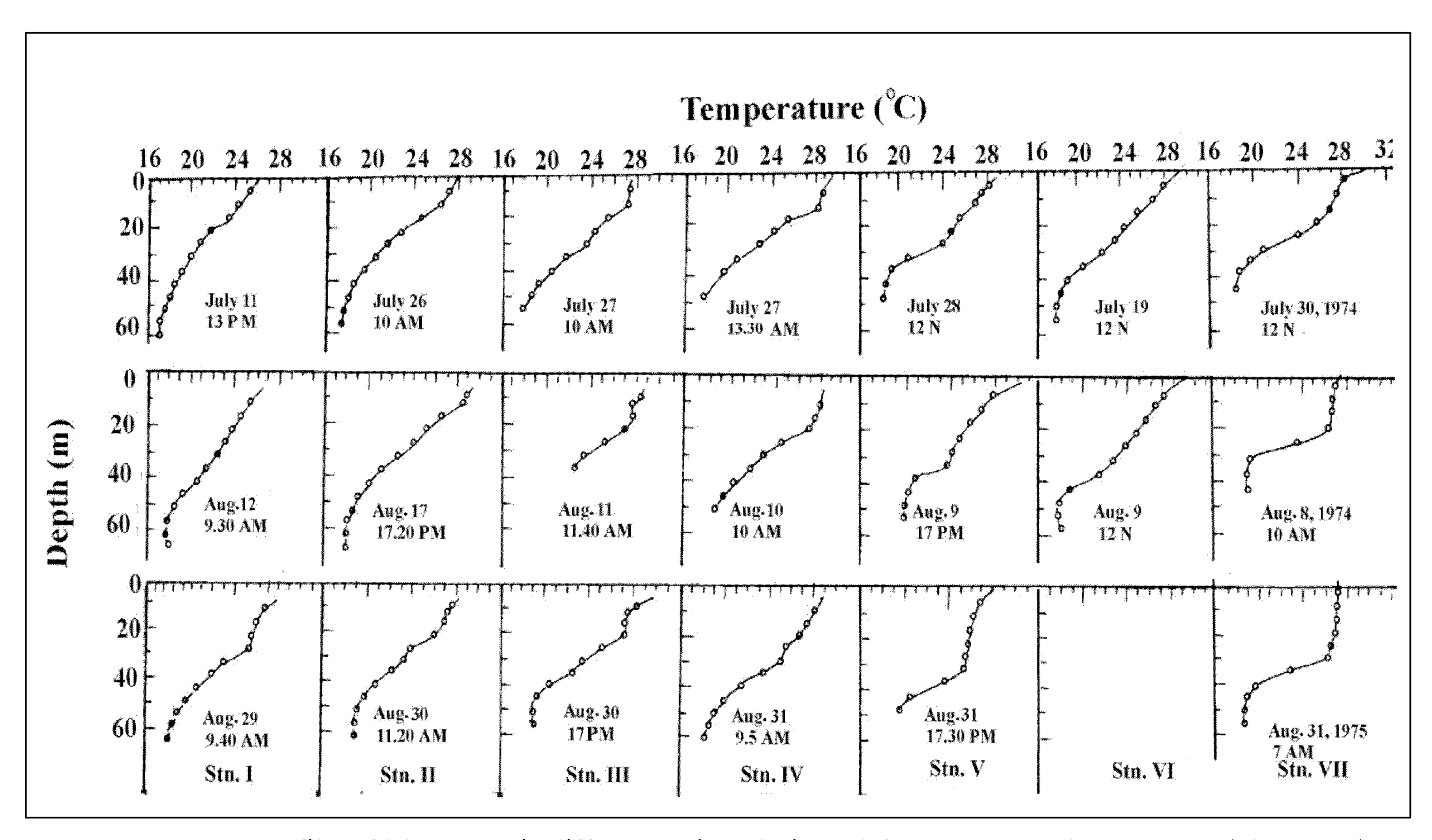


Fig. 26 **Temperature profiles of lake Nasser in different stations during July/August 1974 and August 1975 (Elewa 1980)**
[For stations refer to Table 18, main channel

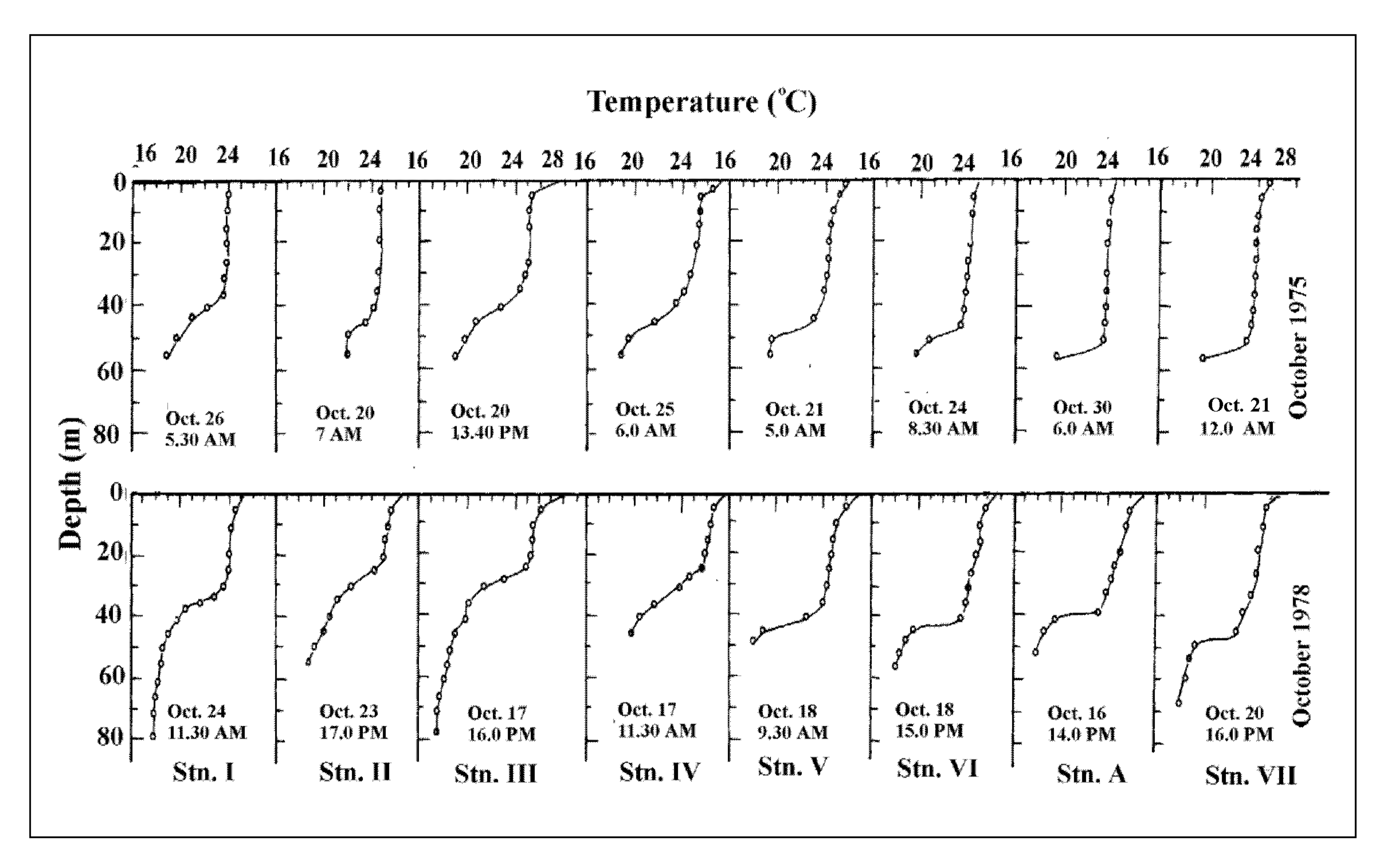


Fig. 27 **Temperature profiles of lake Nasser in different stations during October 1975 and 1978 (Elewa 1980)** [For stations refer to Table 18, main channel].

Table 14 **Monthly and mean annual variations of average values of surface water temperature (°C) in 1983.**

Month	Station						Monthly average
	1	2	3	4	5	6	
Jan.	16.2	16.1	16.6	17.3	16.4	15.9	16.4
Feb.	15.2	15.8	14.4	16.1	15.4	15.7	15.8*
Mar.	15.7	15.8	16.2	16.3	16.0	16.2	16.0
Apr.	17.1	18.8	18.6	18.2	19.0	16.6	18.1
May	21.3	20.4	21.7	20.5	22.4	20.6	21.1
June	20.3	24.1	24.8	23.2	27.1	25.0	24.0
July	23.4	25.0	27.1	22.9	26.9	26.8	25.3
Aug.	22.7	21.9	25.8	23.8	23.0	24.1	23.5
Sep.	25.9	27.1	27.6	25.3	26.7	27.1	26.6**
Oct.	23.2	24.6	25.0	23.4	25.1	24.6	24.3
Nov.	21.8	22.2	22.6	22.2	22.5	22.4	22.3
Dec.	19.6	20.1	20.7	21.3	21.1	21.2	20.7
Mean annual	20.2*	21.0	21.9**	20.9	21.8	21.3	21.2

*and ** designate minimum and maximum values, respectively.
Refer to Fig. 4 for stations (Abdel-Rahman & Goma, 1992b).

Table 15 **Average air and surface water temperatures (°C) at different localities in the main channel during 1996 (SECSF 1996).**

Site	Temperature							
	Winter		Spring		Summer		Autumn	
	Air	Water	Air	Water	Air	Water	Air	Water
High Dam	14.2	16.28	25.6	22.67	32	26.7	20.6	18.94
El Ramla	20.8	20.14	26.6	24.99	32	24.9	20.2	20.35
Kalabsha	15.0	17.69	32.2	26.79	35	28.0	18.8	20.93
Allaqi	22.0	19.73	29.2	28.21	33	31.6	21.7	--
El-Madiq	18.3	18.73	33.0	25.56	32	30.0	204	21.35
Korosko	25.9	20.23	33.0	28.11	35	31.7	17.0	22.46
Amada	21.6	22.50	35.8	29.10	30	29.0	26.4	23.39
Tushka	22.8	18.80	30.0	23.44	37	34.0	18.20	22.08
Abu Simbel	18.0	18.56	24.8	27.82	35	36.1	22	21.98

In 1983, the vertical distribution of water temperature showed that the mean annual values were about 23.1 °C at Kalabsha and 22.7 °C at Allaqi, showing slight decrease to 10 m depth (less than about 1 °C) (Goma & Abdel-Rahman 1992a - Figs. 28 and 29). Furthermore, the monthly variation of the Lake water temperature was about 12 °C, with the highest (i.e. 28 - 30 °C) recorded in June-September and the lowest (i.e. 16 °C) in January-March. The minimum water temperatures of 16.1 - 16.2 °C were recorded in March through the water column at Kalabsha (Fig. 28). At Allaqi, the minimum value of 15.8 -15.9 °C was observed from February to March (Goma & Abdel-Rahman 1992a- Fig. 29). This low temperature may be due to wind cooling and to

the weakening of the solar radiation. The maximum water temperature of 27.8 - 30.1 °C was recorded in July-September (summer season) at both stations (Goma & Abdel- Rahman 1992a- Figs. 28 and 29). This high temperature value may be due to the effect of air temperature and the flood which starts in August and the thermocline becomes deeper.

Table 16 **Ranges of water temperature at different stations of Lake Nasser (1973 - 79) Elewa 1980.**

Month/year	High Dam	Kalabsha	Allaqi	El-Madiq	Amada	Tushka	Abu Simbel	Adindan
				Winter				
Feb. 1973	16.6-16.5	---	19.0-16.7	17.3-17.2	20.6-16.3	17.2-16.4	17.6-15.7	16.7-16.1
Dec. 1974	21.0-18.7	22.0-19.6	22.0-21.7	22.2-21.5	21.3-21.0	21.2-21.0	---	20.0-20.2
				Spring				
May 1974	23.0-16.5	23.5-16.7	25.8-20.5	26.5-16.5	25.5-17.5	27.5-18.0	---	25.0-19.5
April 1978	18.0-15.8	19.0-16.0	21.0-16.5	22.5-16.5	26.5-16.5	25.0-16.5	24.0-16.0	23.5-15.9
April 1979	19.5-17.0	22.5-17.8	---	24.0-17.4	26.5-17.0	22.5-18.0	23.0-17.5	---
				Summer				
July 1973	---	28.4-18.4	---	29.4-18.0	27.6-19.4	28.0-19.8	---	---
Aug. 1974	26.0-18.0	29.25-18.0	28.2-22.5	23.5-19.0	30.75-20.2	30.0-18.0	---	27.5-19.2
June 1975	25.7-17.0	---	26.5-17.7	27.7-17.0	28.0-18.0	27.5-17.0	---	19.0-17.7
July 1975	27.5-17.7	30.1-17.7	28.0-17.5	28.2-17.0	---	31.8-17.5	---	16.7-18.0
Aug. 1975	27.4-18.2	28.4-19.0	31.4-19.2	28.7-18.2	28.5-19.5	---	---	27.6-18.7
July 1979	---	28.0-18.8	28.0-19.0	---	28.5-18.8	28.2-19.0	28.7-18.7	---
				Autumn				
Oct. 1975	24.2-18.7	24.7-22.0	28.7-19.0	26.7-19.0	25.7-19.7	26.2-22.6	24.0-19.5	24.9-19.5
Oct. 1978	25.0-17.1	26.5-19.0	28.5-17.7	26.7-19.9	25.7-18.5	26.0-18.2	27.4-18.0	25.2-18.2

The monthly fluctuations of water temperature at 0 and 20 m depth in the Lake during 1984, and the vertical distribution of mean water temperature of the Lake in February, March, August and November 1984 showed that in January and February, the water temperature was almost constant in the water column at all stations, while in June, July and August the surface temperature was higher than that in deeper layers and the water column was well stratified (Figs. 30 and 31).

The vertical and seasonal variations of water temperature at six stations in Lake Nasser were studied during 1985 (Abdel-Rahman & Goma 1992c) and the results indicated that the lowest temperature was recorded in January and March respectively (Fig. 32). It ranged from 17.9 to 19.4 °C in January, from 17.0 to 20.8 °C in February, and from 16.5 to 21.4 °C in March (Fig. 32). The highest temperature was recorded from June to August. Thus, it ranged from 17.6 to 30.6 °C in June, from 17.9 to 32.0 °C in July and from 18.0 to 30.7 °C in August.

The average difference in water temperature between the near bottom and surface water was 13.3°C during the warm season, while it was 3.4 °C during the cold season. The water temperature was the same in the water column at all stations in January and February because of convection. However, the water column was well stratified from June to August (Kihara 1989).

It is worth mentioning that at six stations (Fig. 4) along the main channel of Lake Nasser in different years, during summer a remarkable thermocline is observed (Fig. 33). The surface temperature reached a maximum for the whole year (Fig. 34), and the extreme surface temperature recorded was 29.8 °C. Generally, the temperature difference between surface and bottom waters shows a wide range in summer (Fig. 34). The temperature difference was high (i.e. 9.3, 9.3, 10.4, 9.5 and 8.8 °C) during the years 1973, 1974, 1975, 1979 and 1983 respectively (Fig. 34). A less temperature difference (i.e. 3.8 - 5.5 °C) was recorded during the years 1984, 1986, 1987, 1988 and 1989 (Fig. 34).

Table 17 **Surface and bottom water temperatures (°C) in the main channel of Lake Nasser during the period of June to August 1973-1979 (Elewa 1980).**

Month	Year	Surface temperatures		Bottom temperatures	
		Lowest	Highest	Lowest	Highest
July	**1973**	27.6	29.4	18.0	20.3
July	**1974**	26.0	30.5	17.0	18.6
Aug.	**1974**	26.0	30.75	18.0	22.5
June	**1975**	25.7	29.0	19.0	18.0
July	**1975**	26.7	31.8	17.0	18.0
Aug.	**1975**	27.4	31.4	18.2	19.5
July	**1979**	28.0	28.7	18.8	19.0

Table 18 **List of main stations in the main channel, and their distance from the High Dam.**

Station number	Site	Distance (km from HD) (upstream)
I	High Dam (H.D)	3
II	Kalabsha	50
III	Allaqi	100
IV	El-Madiq	140
V	Amada	200
VI	Tushka	250
A	Abu Simbel	275
VII	Adindan	290

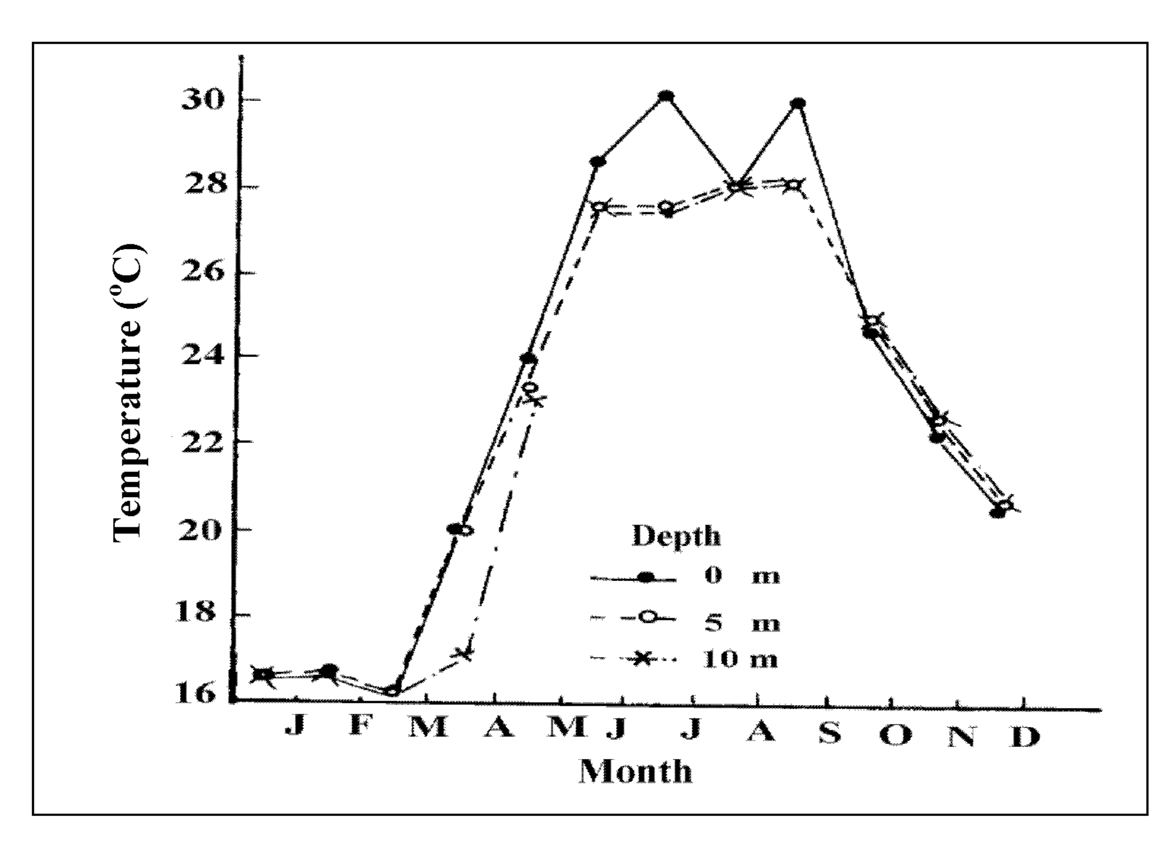


Fig. 28 **Monthly variations of water temperature at station 2 (Kalabsha) in 1983 (Goma & Abdel-Rahman 1992a).**

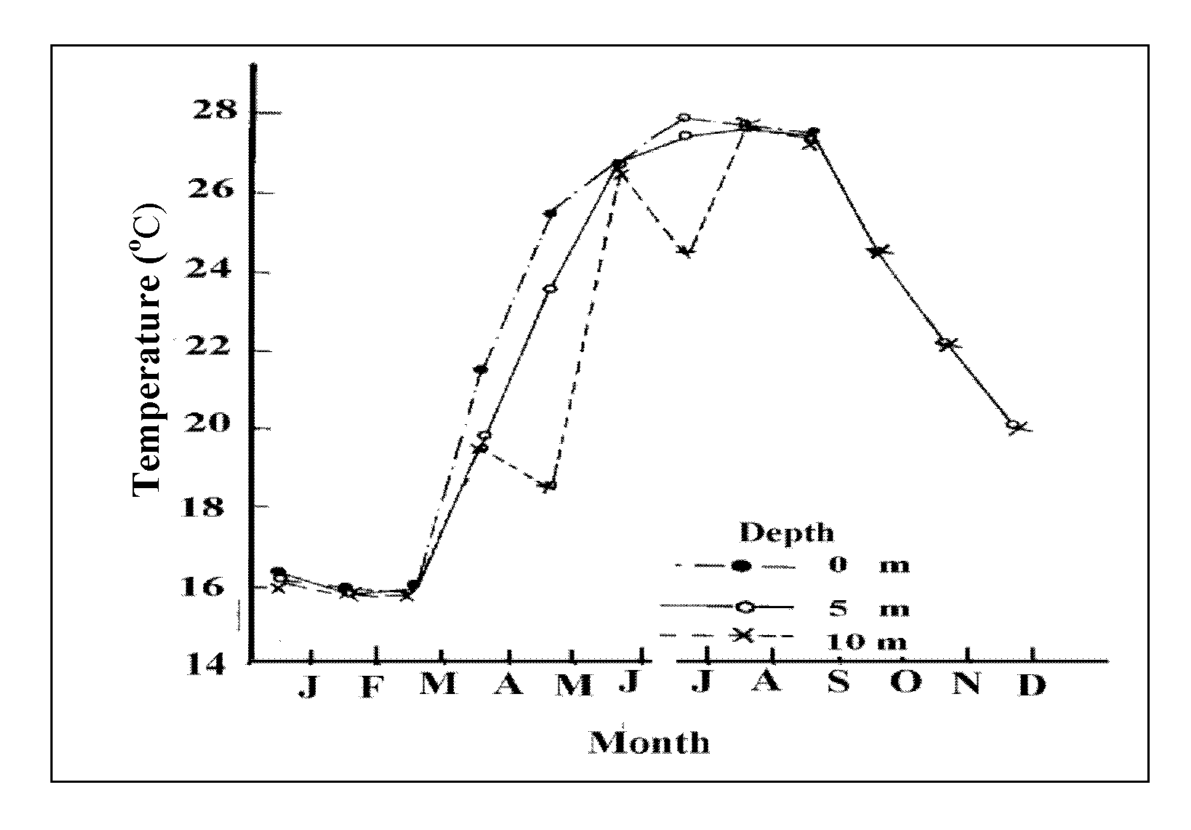


Fig. 29 **Monthly variations of water temperature at station 3 (Allaqi) in 1983 (Goma & Abdel-Rahman 1992a).**

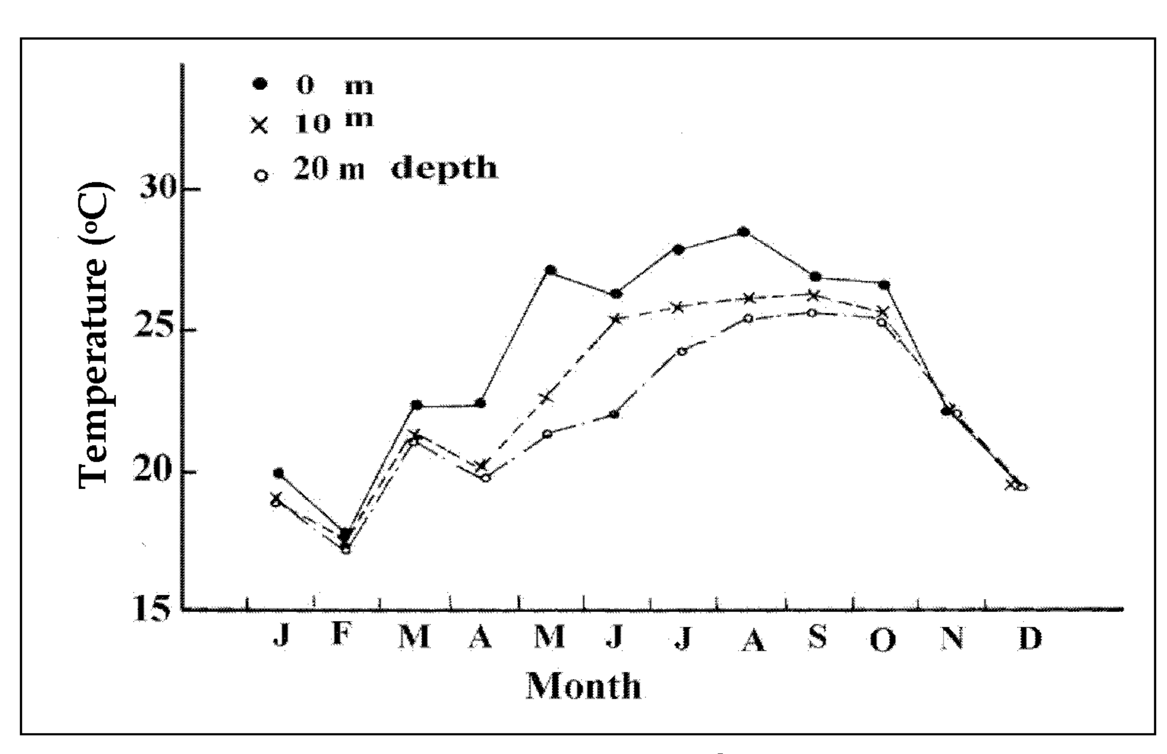


Fig. 30 **Monthly fluctuation of water temperature (°C) at 0, 10, 20 m depth in Lake Nasser in 1984 [mean value of six stations] (Goma & Abdel-Rahman 1992b).**

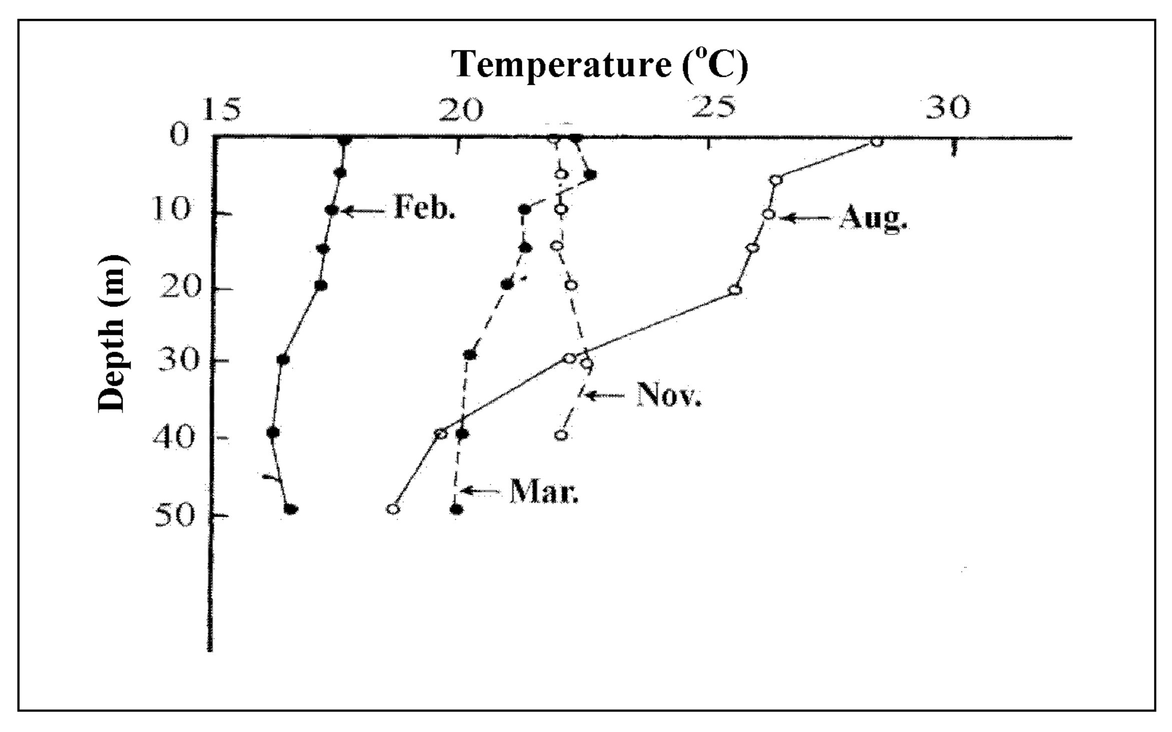


Fig. 31 **Vertical distribution of mean water temperature of Lake Nasser in February, March., August. and November 1984 [mean value of six stations] (Goma & Abdel-Rahman 1992b).**

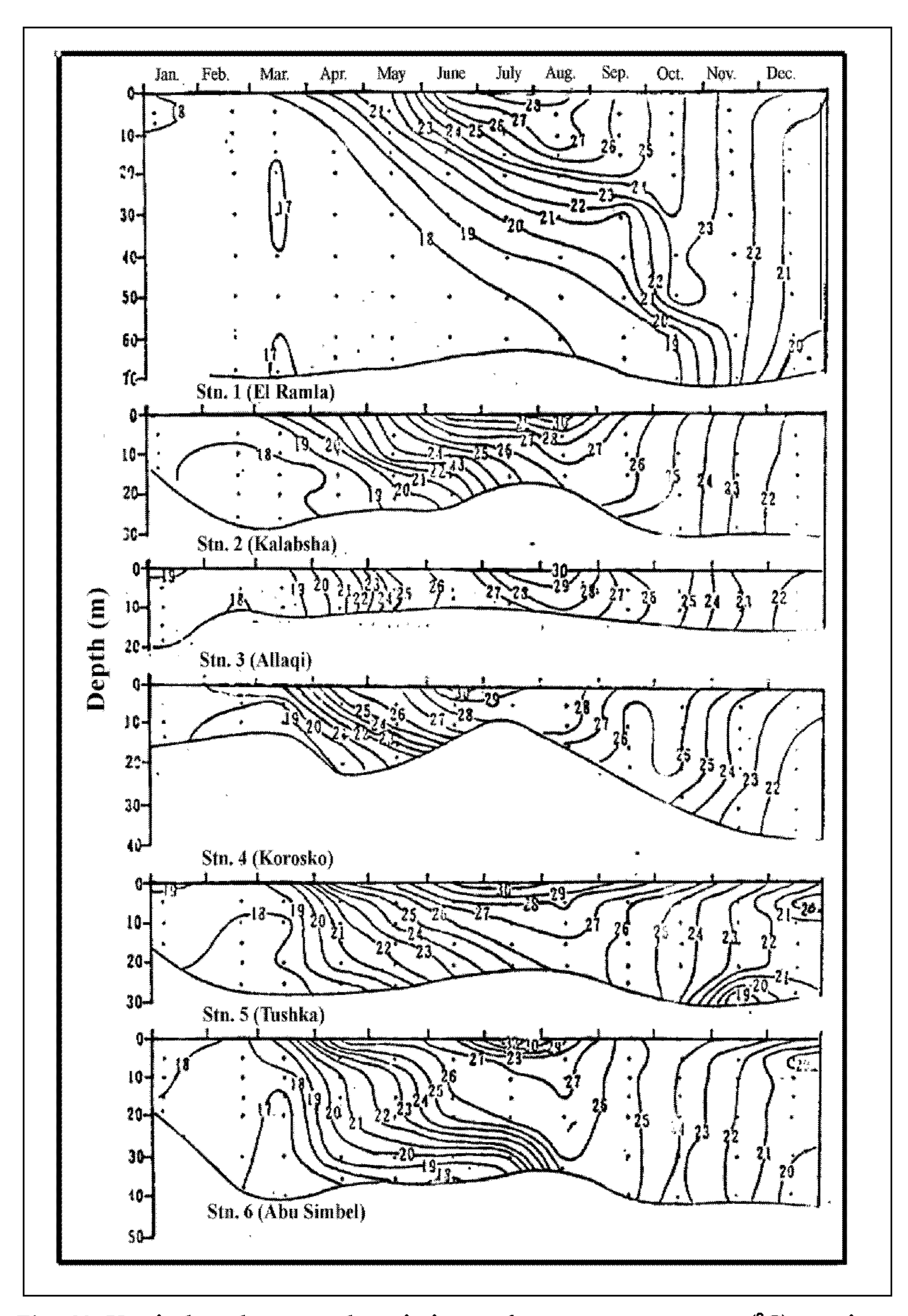


Fig. 32 **Vertical and seasonal variations of water temperature (°C) at six stations along the main channel of Lake Nasser in 1985 (Abdel-Rahman & Goma 1992c.) [**Refer to Fig. 4 for stations**].**

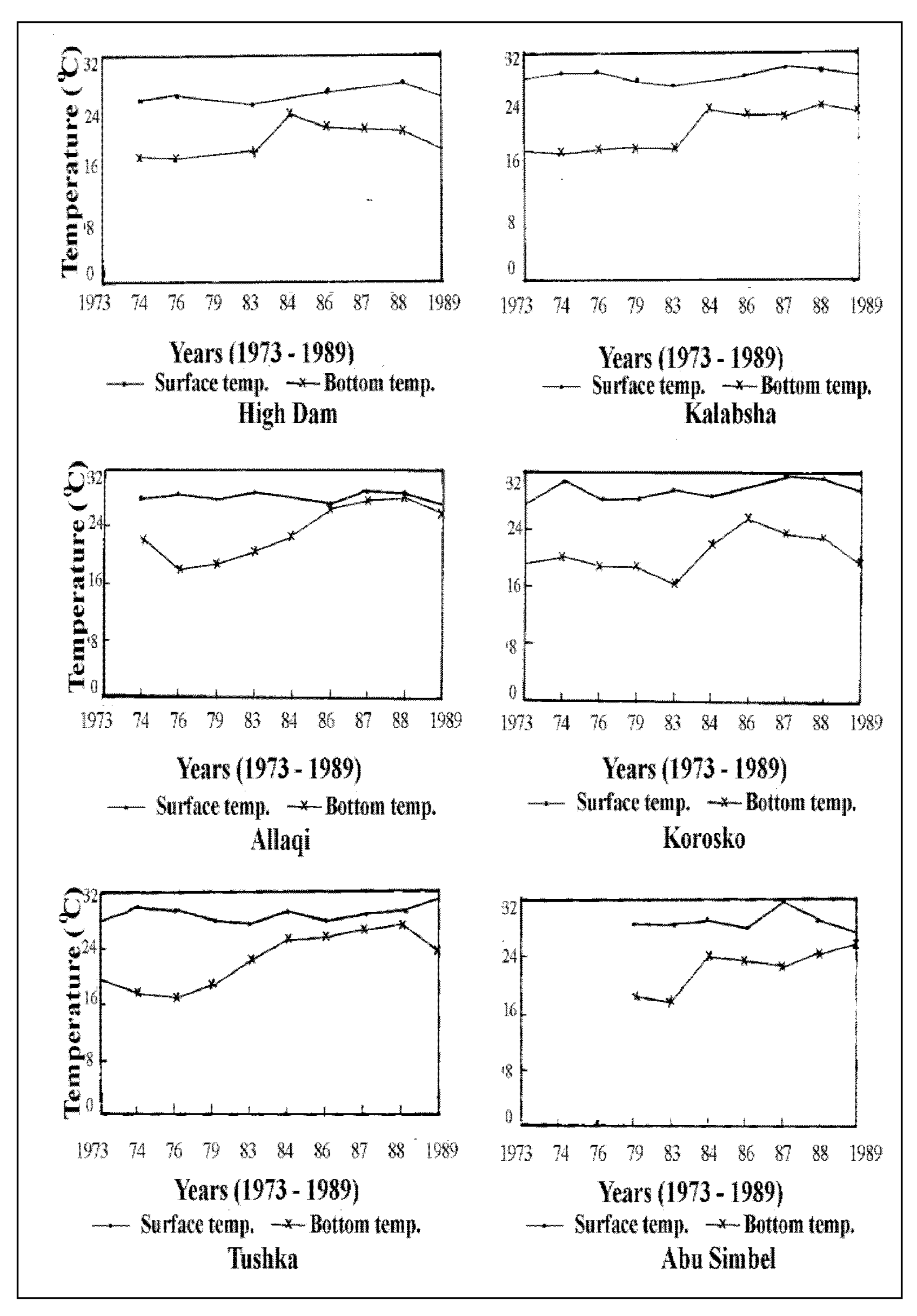


Fig. 33 **Mean surface and bottom water temperatures (°C) at six stations along the main channel of Lake Nasser during summer at different years [1973-1989] (Belal *et al.* 1992).**

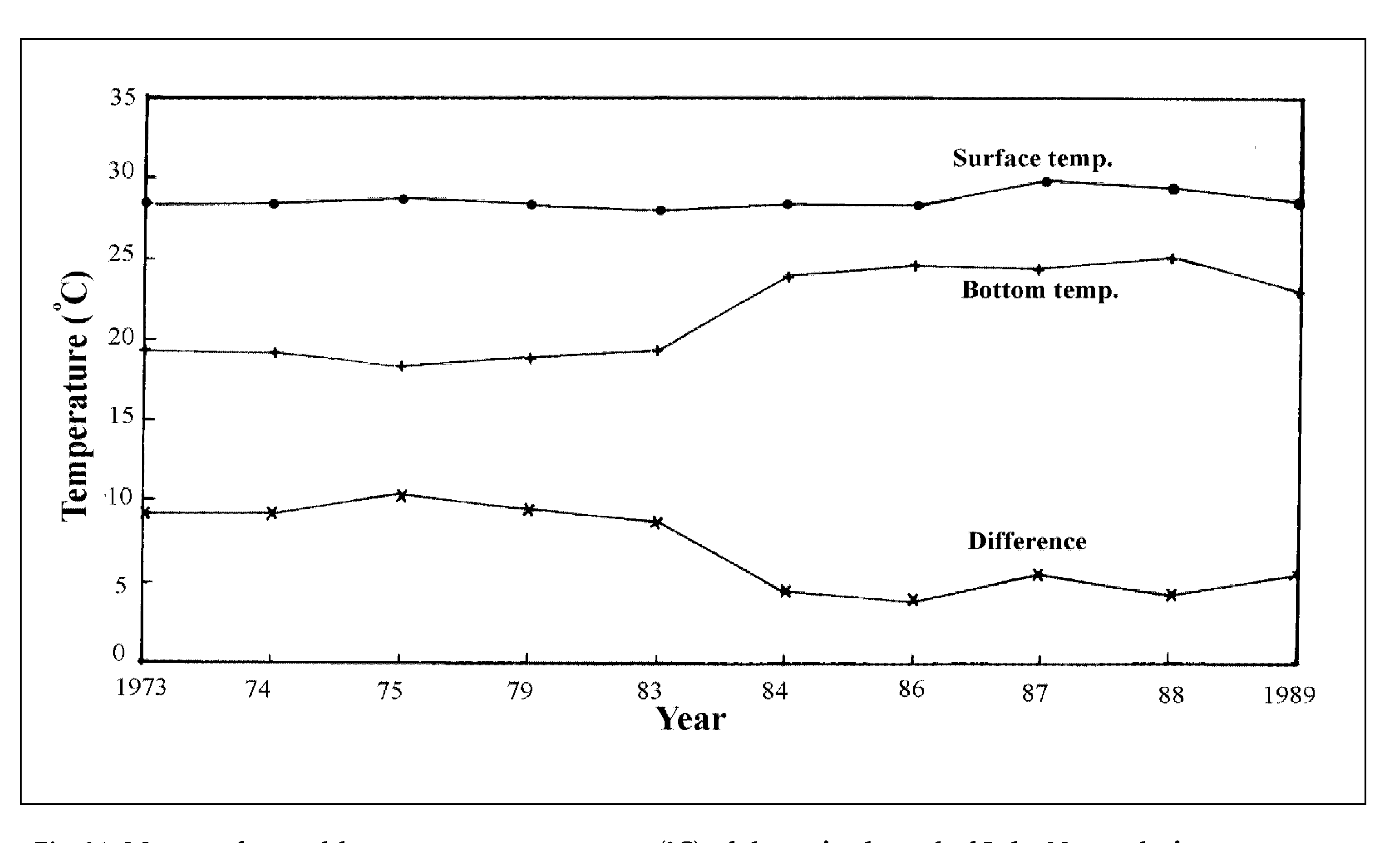


Fig. 34 **Mean surface and bottom water temperatures (°C) of the main channel of Lake Nasser during summer at different years [1973 - 1989] (Belal *et al.* 1992).**

Considering the vertical distribution of water temperature at six stations in Lake Nasser in winter (January) and summer (August) during the period 1987 - 1992 (Tables 19 - 24), the lowest water temperatures were recorded in January, the highest in August. However, the highest surface water temperature (33.3 °C) was recorded in August 1988 at Korosko (Table 22), the lowest (14.75 °C) at 50 m depth at Abu Simbel in January 1992.

The water temperature decreases sharply with depth in summer (August), (Tables 19 - 24) at all stations during the whole period (1987 - 1992). In winter, the water columns are well mixed with almost homogenous temperature. Table 25 shows ranges and differences (surface - deepest) of water temperature at six stations in January and August during 1987 - 1992, indicating remarkable differences in summer and suggesting sharp stratification in the water column.

Fishar (1995) studied the seasonal variations of air, surface water and bottom water temperatures at the eastern side, main channel and western side of Lake Nasser during 1993 (Fig. 35) and his results are summarized as follows:

1. In winter, the average value of surface water temperature along the eastern side, main channel and the western side are 20.35, 20.51 and 21.17 °C respectively, no thermal stratification is observed, as the temperature shows slight difference between surface and bottom water (Fig. 35). The temperature differences between surface and bottom water temperatures are 0.22, 1.57 and 0.96 °C at the eastern side, the main channel and the western side, respectively.

2. In spring, a slight increase in surface water temperature is observed in the eastern and western sides, while a pronounced decrease in the bottom water temperature of the main channel is recorded. The difference between surface and bottom water temperatures is clear especially in the main channel.

3. In summer, the surface and bottom water temperatures attain their maximum average values recorded during 1993. The highest temperature values (33.5 and 30.3 °C), are recorded in the surface and bottom water of the western stations of Maryia and eastern station of Singari.

4. In autumn, the surface and bottom water temperatures, decrease more than their corresponding summer values by about 1.92 °C and 1.99 °C (Fig. 35).

Table 19 **Vertical variation of water temperature at El Ramla station during January and August (1987-1992).**

Depth (m)	Water temperature (°C)											
	1987*		1988*		1989*		1990*		1991**		1992**	
	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.
0	17.5	27.2	17.8	29.90	17.5	28.2	17.50	27.90	19.40	28.0	16.44	28.49
5	17.2	26.9	17.70	29.42	17.3	27.2	17.54	27.55	19.39	26.82	16.44	27.80
10	17.2	25.2	17.70	28.30	17.0	26.1	17.53	26.18	19.12	25.88	16.35	27.56
15	17.1	25.1	17.60	27.12	16.9	25.3	17.43	24.07	19.12	24.29	16.27	24.87
20	17.2	24.4	17.60	25.85	17.0	22.6	17.49	22.25	19.19	23.72	16.30	20.13
30	17.1	21.6	17.70	23.68	17.0	20.3	17.44	19.37	19.39	22.82	16.25	19.56
40	17.1	20.7	17.60	20.86	17.0	17.8	17.49	18.72	19.12	20.27	16.61	17.19
50	17.1	20.5	17.5	19.38	16.9	16.9	17.44	18.30	19.07	19.10	16.30	17.07
60	17.1	---*	17.5	18.85	17.0	16.5	17.32	18.13	19.03	18.51	16.14	16.92
70	17.0	---	---	---	16.9	16.4	17.32	18.06	19.03	18.34	16.02	16.89
75	---	---	---	---	---	---	17.18	---	---	---	---	---
80	---	---	---	---	---	---	---	---	---	---	16.96	---

* Abdel-Rahman & Goma (1995a, b, c & d). ** Abdel-Rahman (1995a & b) [For stations refer to Fig. 4]. (---)* not recorded.

Table 20 **Vertical variation of water temperature at Kalabsha station during January and August (1987-1992).**

Depth (m)	Water temperature (°C)											
	1987*		1988*		1989*		1990*		1991**		1992**	
	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.
0	17.1	31.4	18.0	31.5	17.1	29.7	17.90	31.4	20.50	29.30	16.70	30.45
5	17.2	28.8	17.62	30.20	16.9	29.1	17.81	28.38	19.49	28.23	16.53	29.44
10	17.1	27.5	17.50	28.86	16.9	28.2	17.81	28.18	19.41	27.88	16.50	29.22
15	16.9	25.0	17.37	27.59	16.7	26.1	17.60	24.71	19.33	25.15	16.24	25.99
20	16.9	---	17.29	26.40	16.8	---	17.64	22.58	19.39	14.60	16.27	22.99
30	16.7	---	17.35	---	---	---	17.55	20.42	19.33	22.97	16.20	20.07
40	---	---	---	---	---	---	17.59	18.93	19.64	20.31	16.58	18.54
50	---	---	---	---	---	---	17.53	18.42	19.21	18.82	16.10	17.48
60	---	---	---	---	---	---	17.47	18.29	19.21	18.51	15.96	17.04
70	---	---	---	---	---	---	17.52	18.11	19.18	18.49	16.07	16.90
75	---	---	---	---	---	---	17.32	---	19.12	---	---	---
80	---	---	---	---	---	---	---	---	---	18.41	16.00	16.75

* Abdel-Rahman & Goma (1995a, b, c & d). ** Abdel-Rahman (1995a & b) [For stations refer to Fig. 4].

Table 21 **Vertical variation of water temperature at Allaqi station during January and August (1987-1992).**

Depth (m)	Water temperature (°C)											
	1987*		1988*		1989*		1990*		1991**		1992**	
	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.
0	16.2	29.7	17.00	29.80	16.9	30.8	17.90	27.50	19.60	28.10	16.40	30.32
5	16.9	29.3	16.89	30.02	16.8	30.8	17.76	27.59	19.11	28.05	16.48	29.12
10	16.9	---	16.75	29.32	16.8	28.7	17.77	27.62	19.69	27.87	16.49	29.03
15	16.8	---	---	---	16.7	27.3	17.66	25.28	19.67	27.61	16.39	28.74
20	---	---	---	---	16.5	---	17.66	---	---	---	16.44	23.66
30	---	---	---	---	---	---	---	---	---	---	16.72	19.62
40	---	---	---	---	---	---	---	---	---	---	16.53	17.78
50	---	---	---	---	---	---	---	---	---	---	16.39	16.84
60	---	---	---	---	---	---	---	---	---	---	16.46	16.79
70	---	---	---	---	---	---	---	---	---	---	16.39	16.57

* Abdel-Rahman & Goma (1995a, b, c & d). ** Abdel-Rahman (1995a & b) [For stations refer to Fig. 4].

Table 23 **Vertical variation of water temperature at Tushka station during January and August (1987-1992).**

Depth (m)	Water temperature (°C)											
	1987*		1988*		1989*		1990*		1991**		1992**	
	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.
0	18.0	31.8	18.80	33.30	18.0	32.1	18.90	29.10	21.10	30.50	16.80	29.50
5	18.1	28.8	18.19	30.02	17.94	26.9	18.72	28.80	20.98	29.00	17.51	29.12
10	18.0	28.4	18.11	29.89	17.69	28.8	18.72	28.48	20.92	28.50	17.51	28.61
15	18.0	27.1	18.06	29.77	17.60	26.3	17.61	26.43	21.08	26.52	17.34	26.87
20	18.0	26.8	18.01	27.93	17.62	26.1	18.63	25.52	20.48	26.23	17.64	26.29
30	17.6	---	---	26.30	16.50	21.2	18.53	19.67	20.54	24.52	16.91	28.20
40	---	---	---	23.44	---	---	---	---	---	---	---	---
50	---	---	---	---	---	18.7	18.32	18.59	20.40	21.56	16.27	20.42
60	---	---	---	---	---	---	18.11	18.17	19.52	19.64	16.19	24.19
70	---	---	---	---	---	---	17.96	18.04	---	18.63	16.12	19.52

* Abdel-Rahman & Goma (1995a, b, c & d). ** Abdel-Rahman (1995a & b) [For stations refer to Fig. 4].

Table 22 **Vertical variation of water temperature at Korosko station during January and August (1987-1992).**

Depth (m)	Water temperature (°C)											
	1987*		1988*		1989*		1990*		1991**		1992**	
	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.	Jan.	Aug.
0	16.6	30.0	17.30	31.81	16.40	33.2	17.60	29.10	19.60	30.21	17.20	31.15
5	16.6	29.5	16.83	29.86	16.2	29.3	17.63	28.29	19.76	28.59	16.63	28.57
10	16.6	28.6	16.71	29.25	16.2	27.1	17.63	27.65	19.71	28.03	16.38	27.58
15	16.5	27.7	16.68	29.25	16.1	26.5	17.64	26.21	19.80	28.33	16.38	26.32
20	16.4	---	16.73	29.14	16.1	24.6	17.64	23.68	19.65	27.26	16.31	26.17
30	16.3	---	---	28.37	---	24.6	17.54	19.64	19.66	25.28	16.02	20.56
40	---	---	---	---	---	---	17.54	18.72	19.65	22.22	15.87	18.46
50	---	---	---	---	---	---	17.34	18.19	19.45	19.19	15.16	17.42

* Abdel-Rahman & Goma (1995a, b, c & d). ** Abdel-Rahman (1995a & b) [For stations refer to Fig. 4].

Table 25 **The ranges and differences in water temperatures at six stations (1987 - 1992).**

Year	Month		El Ramla	Kalabsha	Allaqi	Korosko	Tushka	Abu Simbel
1987	January	Depth (m)	0 - 70	0 - 30	0 - 15	0 - 27	0 - 27	0 - 37
		Range (ºC)	17.0 – 17.5	16.7-17.2	16.2-16.9	17.6-18.1	16.3 - 16.6	15.8 - 16.8
		Diff. (ºC)	0.5	0.5	0.7	0.5	0.3	1.0
	August	Depth (m)	0 - 50	0-15	0-5	0 - 20	0 - 15	0 - 20
		Range (ºC)	20.5 – 27.2	25.0-31.4	29.3-29.7	26.8-31.8	27.7 - 30.0	32.1 - 28.6
		Diff. (ºC)	6.7	6.4	0.4	5.0	2.3	5.5
1988	January	Depth (m)	0 - 65	0-30	0 -10	0 - 20	0 - 20	0 - 35
		Range (ºC)	17.5 – 17.8	17.29-18.0	16.75-17.00	18.01-18.80	16.68 - 17.30	16.29 -16.50
		Diff. (ºC)	0.3	0.71	0.25	0.79	0.26	0.21
	August	Depth (m)	0 - 60	0 -20	0 -10	0 - 35	0 - 30	0 - 25
		Range (ºC)	18.85 – 29.90	26.40-31.5	29.32-30.02	23.44-33.30	28.37-30.80	29.05 - 32.20
		Diff. (ºC)	11.05	5.10	0.70	9.86	1.43	3.15
1989	January	Depth (m)	0 - 70	0 -20	0 -20	0 - 30	0 - 25	0 - 30
		Range (ºC)	16.9 – 17.5	16.7 – 17.1	16.5 – 16.9	16.5 – 18.0	16.1 – 16.4	15.8 – 15.9
		Diff. (ºC)	0.6	0.4	0.4	1.5	0.3	0.1

Table 24 **Vertical variation of water temperature at Abu Simbel station during January and August (1987-1992).**

Depth (m)	1987* Jan.	1987* Aug.	1988* Jan.	1988* Aug.	1989* Jan.	1989* Aug.	1990* Jan.	1990* Aug.	1991** Jan.	1991** Aug.	1992** Jan.	1992** Aug.
	Water temperature (°C)											
0	16.8	23.2	16.5	32.20	15.80	28.50	17.50	27.50	19.20	29.00	15.70	29.18
5	16.1	28.6	16.33	29.27	15.90	28.40	17.31	27.66	19.28	28.70	15.75	27.57
10	16.0	27.8		29.20	15.90	27.30	17.11	27.08	19.25	27.91	15.82	27.46
15	15.9	27.4	16.37	29.20	15.80	26.90	17.01	26.45	19.44	27.99	15.80	27.20
20	16.0	23.1	16.29	29.14	15.90	26.80	16.99	24.24	19.24	27.59	15.86	27.00
25	15.9	---	--	29.05	---	---	---	---	---	---	---	---
30	15.9	---	16.29	---	15.80	---	17.01	20.20	19.05	25.57	15.07	22.33
35	---	---	16.37	---	---	---	---	---	---	---	14.92	---
40	15.8	---	---	---	---	---	16.90	19.01	19.80	21.02	14.92	18.26
50	---	---	---	---	---	---	---	18.83	19.26	20.26	14.75	17.67

* Abdel-Rahman & Goma (1995a, b, c & d). ** Abdel-Rahman (1995a & b) [For stations refer to Fig. 4].

Cont. ***Table 25***

Year	Month		El Ramla	Kalabsha	Allaqi	Korosko	Tushka	Abu Simbel
		Depth (m)	0 - 70	0 - 15	0 - 15	0 - 40	0 - 30	0 - 20
	August	**Range (°C)**	16.4 - 28.2	26.1-29.7	27.3 - 30.8	18.7 - 32.1	24.6 - 33.2	26.8 – 28.5
		Diff. (°C)	11.8	3.6	3.5	3.4	8.6	1.7
1990		**Depth (m)**	0 - 75	0 - 70	0 - 20	0 - 60	0 - 50	0 - 40
	January	**Range (°C)**	17.18 - 17.54	17.32 - 17.90	17.66 - 17.90	17.96 - 18.90	17.34 -7.64	16.90-17.50
		Diff. (°C)	0.36	0.58	0.24	0.94	0.30	0.60
		Depth (m)	0 - 70	0 - 70	0 - 15	0 - 60	0 - 50	0 - 50
	August	**Range (°C)**	18.06 - 27.90	18.11 - 31.40	25.28 - 27.62	18.04 - 29.10	18.19 – 29.10	19.05-19.80
		Diff. (°C)	9.84	13.29	2.34	11.06	10.91	8.83
1991		**Depth (m)**	0 - 70	0 - 75	0 -15	0 - 50	0 - 50	0 - 50
	January	**Range (°C)**	19.03 - 19.40	19.12 - 20.50	19.11 -19.69	19.52 - 21.10	19.45 - 19.80	20.26-29.00
		Diff. (°C)	0.37	1.38	0.58	1.58	0.35	0.75
		Depth (m)	0 – 70	0 - 80	0 - 15	0 - 60	0 - 50	0 - 50
		Range (°C)	18.34 - 28.00	18.41 - 29.30	27.61 - 28.10	18.63 - 30.5	19.19 – 30.20	14.75-15.86
		Diff. (°C)	9.66	10.89	0.49	11.87	11.01	8.74
1992		**Depth (m)**	0 - 80	0 - 80	0 - 70	0 - 60	0 - 50	0 - 50
	January	**Range (°C)**	16.02– 6.96	16.00 -16.70	16.39 - 16.72	16.12 - 17.64	15.16 –17.20	14.75-15.86
		Diff. (°C)	0.94	0.70	0.33	1.52	2.04	1.11
		Depth (m)	0 - 70	0-80	0 - 70	0 - 60	0 - 50	0 - 50
	August	**Range (°C)**	16.89 – 28.94	16.75 - 30.45	16.57- 30.32	19.52 - 29.50	17.42 - 31.13	17.67-29.18
		Diff. (°C)	12.05	13.70	13.75	9.98	13.71	11.51

N.B. Data are adopted from Abdel- Rahman & Goma (1995a, b, c & d) and Abdel- Rahman (1995a & b) [For stations refer to Fig. 4].

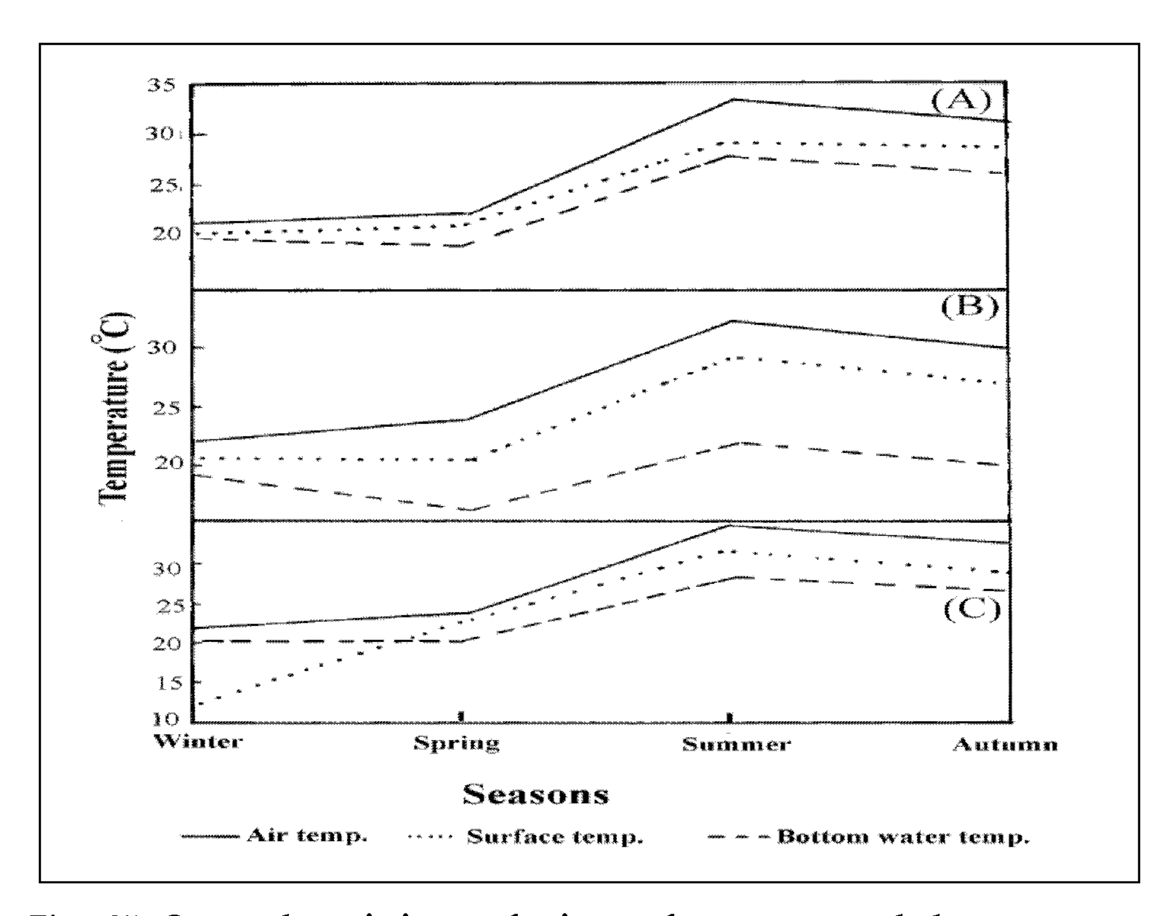


Fig. 35 **Seasonal variations of air, surface water and bottom water temperatures in A: eastern side, B: main channel and C: western side of Lake Nasser during 1993 (Fishar 1995) [**For localities refer to Fig. 15**].**

TRANSPARENCY

The Main Channel. The transparency of the Lake is affected by three important factors : (1) the inflowing turbid water of the River Nile, (2) the development of phytoplankton, and (3) vertical water movement (wind action). The inflowing Nile water, especially during the flood period, is very turbid, rich in suspended inorganic and organic matter and has a brownish-greyish colour. On the arrival of the flood into the Lake the Secchi transparency diminishes within a few hours from 70-140 cm to 20-30 cm or even to 5 -10 cm. The border line between flood water and old water is sometimes very sharp, but the silt content is still remarkable (100-500 mg/1).

Along the progressing flood continuous sedimentation takes place within the Lake, accompanied by gradual reduced turbidity. Ultimately the optical border line between flood water and old water disappears. In areas where the sedimentation has already been completed there is a permanent high transparency in the deeper water layers, of about 300 to 600 cm. In these areas the transparency of the epilimnion is controlled mainly by the phytoplankton. If the phytoplankton density is poor, usually from December to February, the transparency ranges between 200 and 400 cm. As soon as a remarkable algal development starts, usually

in March or April, the transparency is reduced to 80-130 cm or even to values of 50 to 70 cm, in case of a dense water bloom.

Under special conditions, i.e. strong long lasting wind blowing from the shore towards the deep water areas of temperature homogenity, an upwelling current is readily formed, lifting water masses very poor in plankton to the surface. Under such conditions, as on 18/3/74, an extremely high transparency of 754 cm was recorded. After a few days of calm weather the transparency dropped because of renewed and rapid phytoplankton development when conditions became normal again.

An obvious indicator of change of water conditions in man-made lakes is the turbidity, measured by a Secchi disk. High turbidity can be caused by suspended inorganic and organic materials (seston) transported by inflowing waters, or by dense plankton communities. The increased turbidity caused by seston tends to mark the beginning of flood waters through the Lake. These waters being rich in nutrients, plankton blooms soon develop, an additional source of turbidity. In the early years of Lake Nasser filling, a strong "water colouration" appeared in the second half of the flood season, caused mainly by *Volvox* colonies. In Volta Lake *Microcystis* water blooms developed shortly after the flood arrival and transparency was reduced in both cases.

In Lake Nasser the effect of flood is manifested in the arrival of turbid water in July/August starting from the southernmost part of the reservoir and extending northwards to cover Lake Nubia and only the southernmost sector of Lake Nasser. Hurst (1957) pointed out that about 100 million tons of suspended sediments are carried annually with the Nile water on entering Egypt. During flood the transparency of water is few centimeters in the southern part of Lake Nubia, as compared with other regions. From February to April, the transparency difference between Lake Nasser and Lake Nubia is not wide and could be attributed to different plankton loads. The highest transparency appeared only near the High Dam in February 1973, after a few days strong wind drifted the surface water layer with its phytoplankton, causing its replacement by clearer deep water (Fig. 36, Latif 1984a).

The monthly variations of transparency at six stations on Lake Nasser during 1983, 1984, 1986 to 1988, 1991 and 1992 are shown in Tables 26 and 27 and Figs. 37-39. The results indicate that at the beginning of the Nile flood, the quantities of the sediments increase greatly, as shown in the minimum reading of the Secchi disk of 0.5 m at Abu Simbel (Tables 26 and 27) located at the most southern region of the Lake. The average value of suspended matter found at the Egyptian borders during the flood period (August-October) amounted to 1.6 kg/m^3 (Elster & Vollenweider 1961). The maximum reading of Secchi disk was 6.0 m at Korosko in February (Table 26). The monthly average value of transparency varied from 1.3 m in September to 3.5 m in March. The mean annual value was 2.3 m (Abdel-Rahman & Goma 1992b, Table 26). Along the different stations of Lake Nasser, limited variations in transparency were observed and ranged from 0.9 at Abu Simbel in November to 4.9 m at El Ramla in January (Table 27).

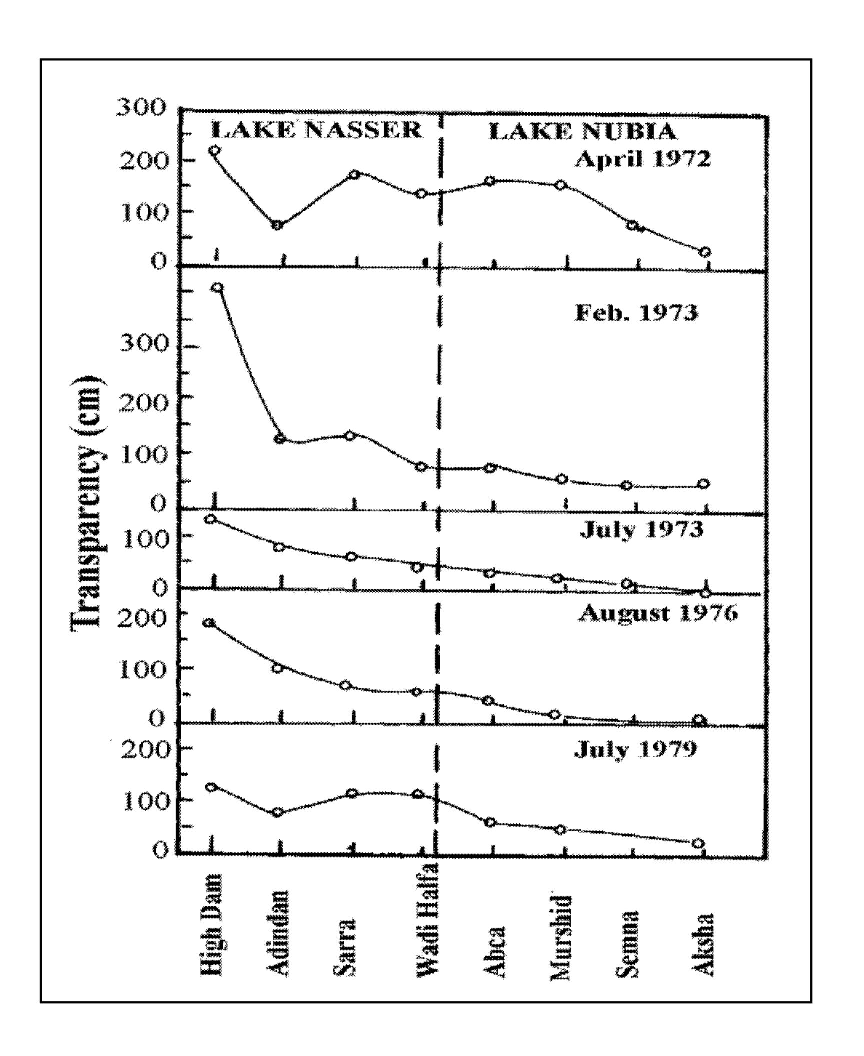


Fig. 36 **Transparency values (cm) of Lake Nasser and Lake Nubia at some selected months (Latif 1984a).**

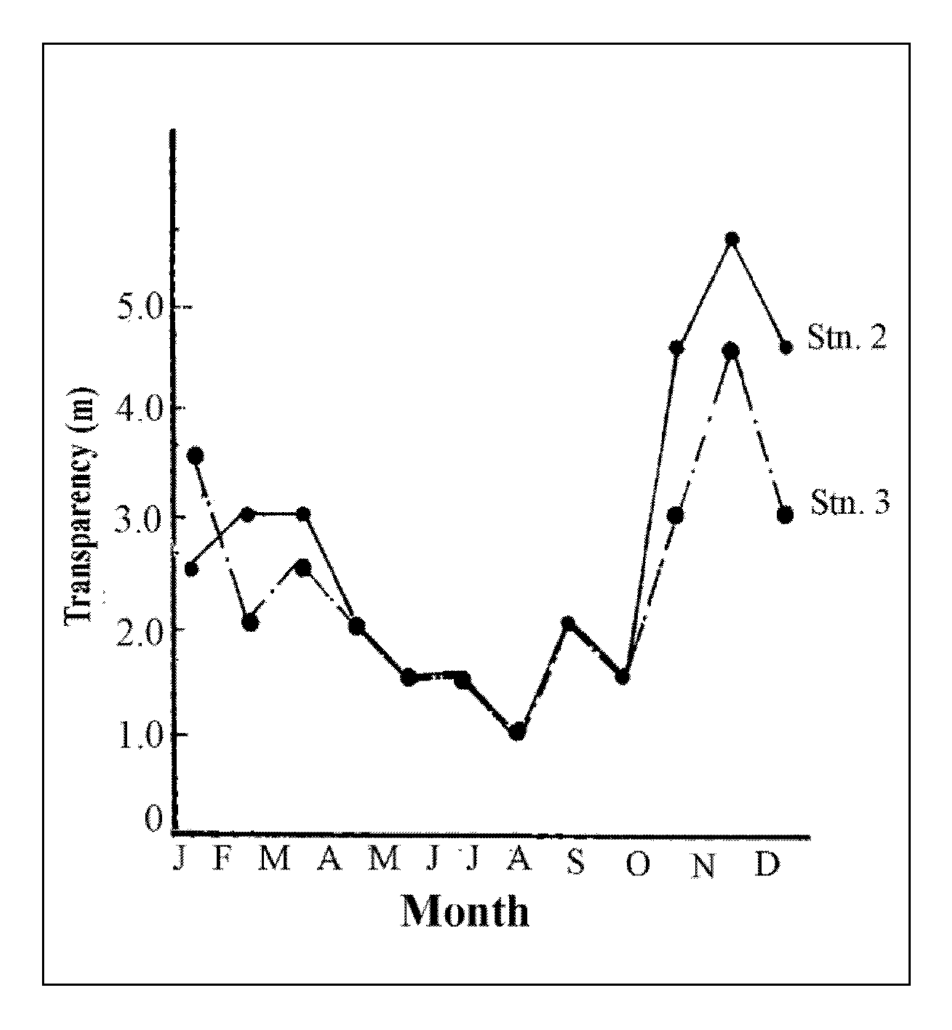


Fig. 37 **Monthly variations of transparency at stations 2 and 3 (Kalabsha & Allaqi) in 1983 (Goma & Abdel-Rahman 1992a)** [For stations refer to Fig. 4].

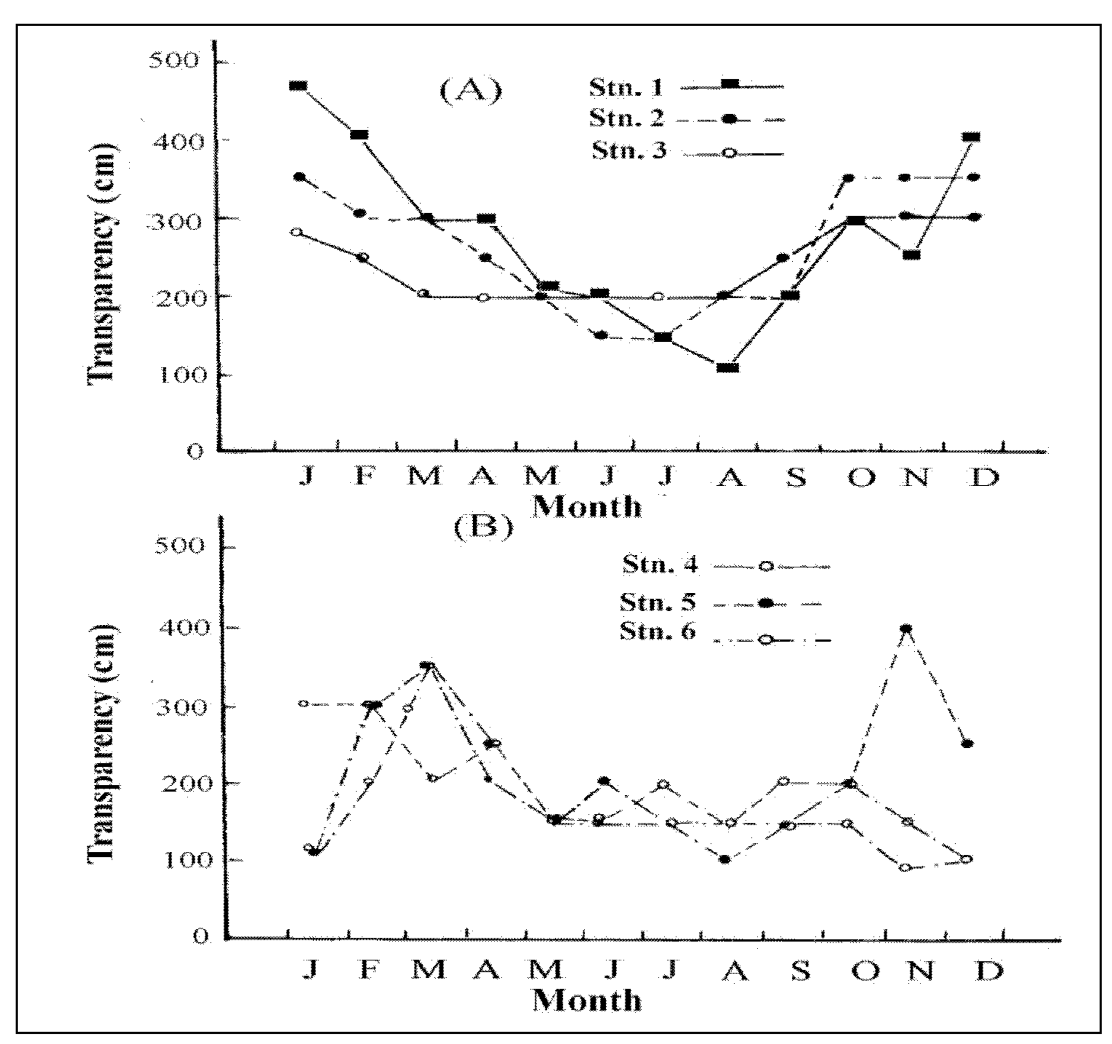


Fig. 38 **The monthly variations of transparency (cm) at six stations of Lake Nasser in 1984 (Goma & Abdel-Rahman 1992b).**

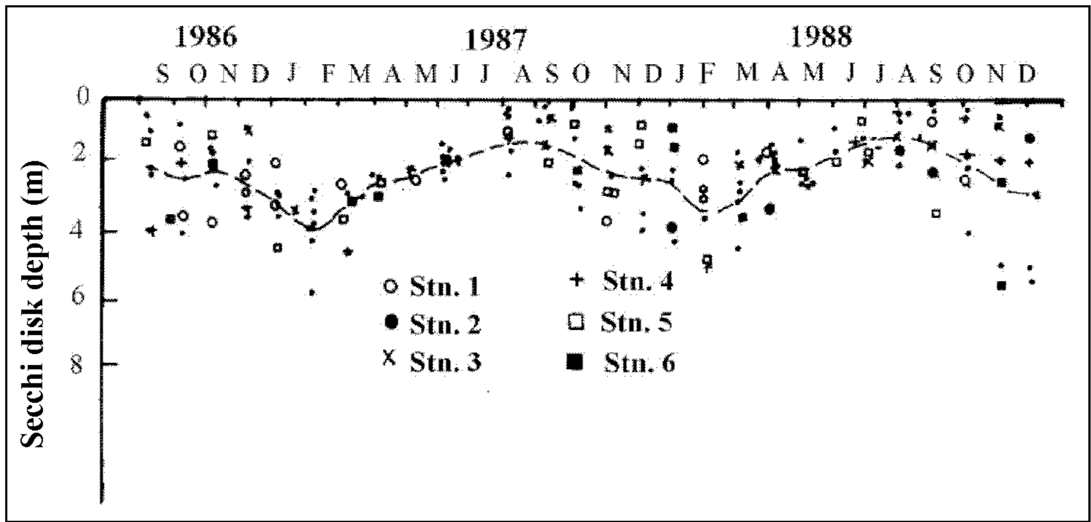


Fig. 39 **Seasonal changes of the Secchi disk depth at stns. 1 - 6 in the main channel of Lake Nasser. The line is for averages of the six stations (Habib *et al.* 1996). [**For stations refer to Fig. 4**].**

From March to September 1984 the transparency was relatively low (1.2 - 3.0 m) at stations of El Ramla, Kalabsha and Allaqi (Figs. 38 and 39) which might be attributed to the abundance of phytoplankton. In winter (December - February) higher transparency values were recorded (Habib *et al.* 1996). Transparency values were low (0.9 - 2.0 m) at Tushka and Abu Simbel except during March. The low values of transparency in the southern region of the Lake might be related to the effects of flood waters bearing large amounts of sediments (Goma & Abdel-Rahman 1992a, Habib *et al.* 1996). Habib *et al.* (1996) pointed out that the level of suspended solids was high (1.0-59.0 g/m^3) at stations 4-6 in the southern region, and low (0.5-10.0 g/m^3) at stations 1-3 in the northern region of the Lake during 1986-1988. The patterns of suspended solids were similar among stations 1-3 and stations 4-6. Rapid increases in suspended solids were recorded in April and May at stations 1-3, whereas at stations 4-6 rapid increases were observed in August and September in 1987 and 1988. The monthly variations of transparency at stations Kalabsha and Allaqi on the main channel of Lake Nasser during 1983 show a maximum value in November and a minimum in May and September (Fig. 37) (Goma & Abdel-Rahman 1992a). Slight difference in transparency measurements between the two stations (El Ramla and Kalabsha) was observed (Fig. 38). The transparency was the same at the two stations during April to September.

Table 26 **Monthly and mean annual variations of transparency (m) at six stations of Lake Nasser in 1983. (**maximum, *minimum) [**For stations refer to Fig. 4**].**

Month	**Stations**						**Monthly average**
	1	**2**	**3**	**4**	**5**	**6**	
Jan.	3.5	2.5	3.5	3.5	2.0	1.0	2.7
Feb.	3.5	3.0	2.0	6.0**	3.0	3.0	3.4
Mar.	4.0	3.0	2.5	4.5	3.0	4.0	3.5**
April	3.0	2.0	2.0	2.0	3.0	4.0	2.7
May	1.5	1.5	1.5	1.5	1.5	2.0	1.6
June	3.0	1.5	1.5	1.0	2.5	1.0	1.8
July	1.5	1.0	1.0	3.0	1.0	1.0	1.4
Aug.	2.0	2.0	2.0	1.3	1.0	1.0	1.6
Sept.	1.5	1.5	1.5	1.5	1.5	0.5*	1.3*
Oct.	3.0	4.5	3.0	1.0	2.0	0.8	2.4
Nov.	3.0	5.5	4.5	2.0	1.5	1.5	3.0
Dec.	3.5	4.0	3.0	2.0	2.0	1.5	2.7
Mean annual	**2.8****	**2.7**	**2.3**	**2.4**	**2.5**	**1.8***	**2.3**

Studies by various investigators on seasonal patterns of Secchi disk readings indicated high values during the low temperature period and lower values during high temperature period (Habib *et al.* 1987 and 1996, Habib & Aruga 1988, Fishar 1995). There seems to be a tendency for Secchi disk depth to be lower in the southern region and higher in the northern region of the Lake

which may be correlated with the decrease of suspended solids with water flow along the main channel (Fig. 40).

The Secchi disk depth was significantly correlated with suspended solids in a hyperbolic manner, when the two parameters were plotted on linear scales (Fig. 40 - Habib *et al.*, 1996).

Table 27 **Monthly changes of transparency at six stations of Lake Nasser during different years (unit : m).**

Month	Year	El Ramla	Kalabsha	Allaqi	Korosko	Tushka	Abu Simbel
Jan.	**1984**	4.7	3.5	2.8	3.0	1.0	1.0
	91	4.9	3.0	2.5	2.7	1.6	1.7
	92	3.9	4.1	4.1	3.9	2.9	1.9
Feb.	**1984**	4.0	3.0	2.5	3.0	3.0	2.0
	91	5.7	3.0	3.0	3.1	2.3	2.1
	92	3.7	4.1	3.3	4.1	1.9	1.3
Mar.	**1984**	3.0	3.0	2.0	2.0	3.5	3.5
	91	5.0	3.8	2.5	3.2	2.7	3.3
	92	5.8	4.2	3.5	2.7	3.0	2.9
April	**1984**	3.0	2.5	2.0	2.5	2.5	2.0
	91	3.3	2.6	2.1	2.0	2.1	2.1
	92	4.8	4.4	3.8	3.2	3.0	2.1
May	**1984**	2.1	2.0	2.0	1.6	1.5	1.5
	91	2.1	2.7	1.9	1.8	2.1	1.8
June	**1984**	2.0	1.5	2.0	1.5	1.5	2.0
	91	1.9	1.8	1.5	1.6	1.5	1.6
July	**1984**	1.5	1.5	2.0	2.0	1.5	1.5
	91	2.2	2.1	2.1	1.6	1.5	1.4
	92	2.7	1.7	2.1	1.3	2.0	1.5
Aug.	**1984**	1.2	2.0	2.0	1.5	1.0	1.5
	91	3.1	3.0	1.8	0.9	0.6	0.6
	92	3.2	4.1	2.2	2.0	1.5	---
Sept.	**1984**	2.0	2.0	2.5	2.0	1.5	1.5
	91	3.8	3.8	1.6	0.5	0.5	0.3
	92	4.8	3.6	2.5	1.3	0.6	0.3
Oct.	**1984**	3.0	3.5	3.0	2.0	2.0	1.5
	91	4.8	3.2	2.8	2.1	1.2	0.6
	92	4.0	3.3	2.5	1.3	1.7	1.4
Nov.	**1984**	2.5	3.5	3.0	4.0	1.5	0.9
	91	4.8	2.9	3.0	1.6	1.0	0.8
	92	4.6	4.7	2.6	2.7	1.0	0.5
Dec.	**1984**	4.0	3.5	3.0	2.5	1.0	1.0
	91	3.9	3.0	3.8	2.8	1.2	0.9

1984 (Goma & Abdel-Rahman 1992b). 1991 (Abdel-Rahman 1995a).
1992 (Abdel-Rahman 1995b). [For stations refer to Fig. 4].

Mohamed, I. (1996b) showed that transparency in the main channel of Lake Nasser during 1992 had a maximum value of Secchi disk depth (5.8 m) at stn. 1 in March, and minimum values (0.3 and 0.4m) at stn. 6 in August and September. The

latter author pointed out that transparency was usually low during the period of high chlorophyll *a* concentration and high during the period of low chlorophyll *a* concentration. Mohamed, I. (1996b) concluded that transparency is due to the presence of both phytoplankton and suspended substances.

Studies on the seasonal variations of Secchi disk readings in Lake Nasser during 1993 (Fig. 41) showed that the Secchi disk depth was high in winter especially in the main channel, where an average value of 278.50 cm was recorded (Fishar 1995). The Secchi disk readings slightly decreased in spring, when average readings of 238.8, 252 and 237.22 cm were recorded for the eastern side, western side and the main channel respectively. It seems that both eastern and western sides of the Lake are more turbid than the main channel. Furthermore, a sharp decrease in transparency value (180.3 cm for the entire Lake in average) was observed in summer, which may be attributed to the new arrival of flood. During autumn, transparency increases slowly and reaches an average of 201.7 cm for the entire Lake (Fishar 1995).

Habib *et al.* (1996) showed that the ignition loss of suspended solids was high (i.e. 25 - 98%) at the northern region (stns. 1-3) and low (i.e. 6-92%) at the southern stations (stns. 4-6) (Fig. 43). Variations of ignition loss were high at stns. 1-3 as compared with those of stns. 4 -6. Rapid increase of ignition loss was observed in August and September at stns. 1-3 in 1987 and 1988, whereas rapid decreases were found at stns 4-6.(southern region) in the same period. These differences may be due to differences of variation in proportion of inorganic suspended solids to the particulate organic matter or to the total suspended solids in the Lake. The patterns of seasonal changes of ignition loss (Fig. 43) were quite different from those of suspended solids (Fig. 42). It is concluded that there are large seasonal variations in the proportion of inorganic suspended solids to the total suspended solids or to the particulate organic matter.

The Khors. Elewa (1987a) mentioned that the transparency in five khors of Lake Nasser (Amicol, Manam, El Birba, Singari and Tushka) was high during the cold season and was lowered by flood turbid water especially in the southern khors at Tushka.

Habib (1995c) described the seasonal changes of the Secchi disk depth, suspended solids and ignition loss at four stations in Khor El Ramla (Figs. 44 - 47). The Secchi disk depth was lowest (1.2 m) in August 1986 at stn. 6, and highest (4.8 m) in February 1987 at stn. 11. The Secchi disk depth was mostly low at stns. 4 and 6, whereas it was high at stns. 10 and 11. The suspended solids were high (5 - 11.5 g/m^3) at stns. 4 and 6 (inside the khor) and comparatively low (i.e. 04-5.2 g/m^3) at stns.. 10 and 11 in the main channel and eastern side of the Lake (Fig. 46). The patterns of seasonal changes of suspended solids are similar among stns. 4 and 6, and also similar among stns. 10 and 11. However, the patterns at stns. 10 and 11 are clearly different from those at stns. 4 and 6 (Habib 1995c).

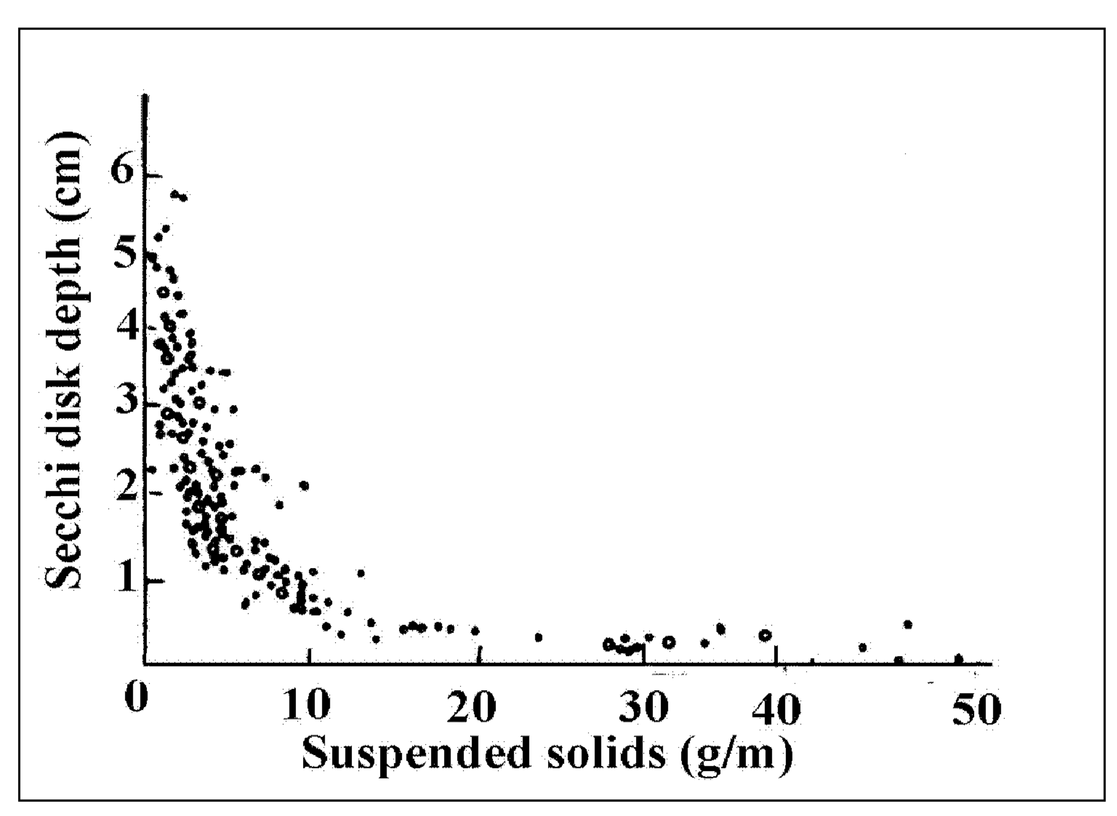


Fig. 40 **Relationships of the Secchi disk depth to the suspended solids at stns. 1-6 in the main channel of Lake Nasser. (o) surface; (•) 2m. (Habib *et al.* 1996)** [For stations refer to Fig. 4].

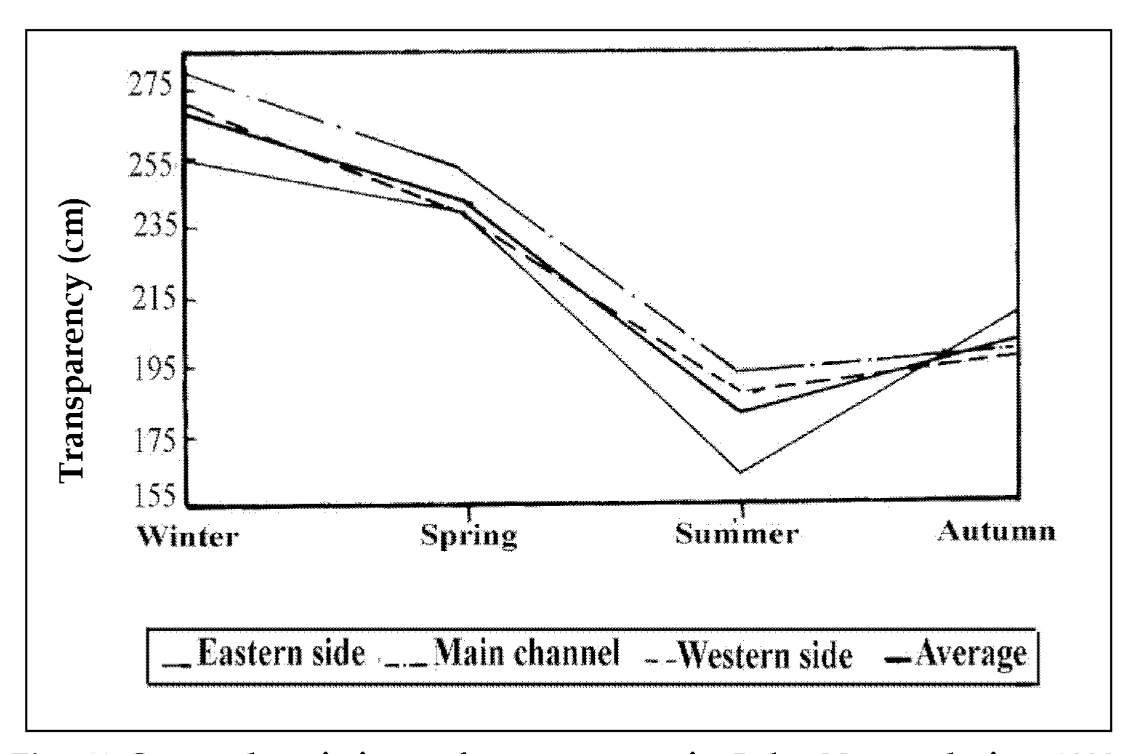


Fig. 41 **Seasonal variations of transparency in Lake Nasser during 1993. (Fishar 1995).**

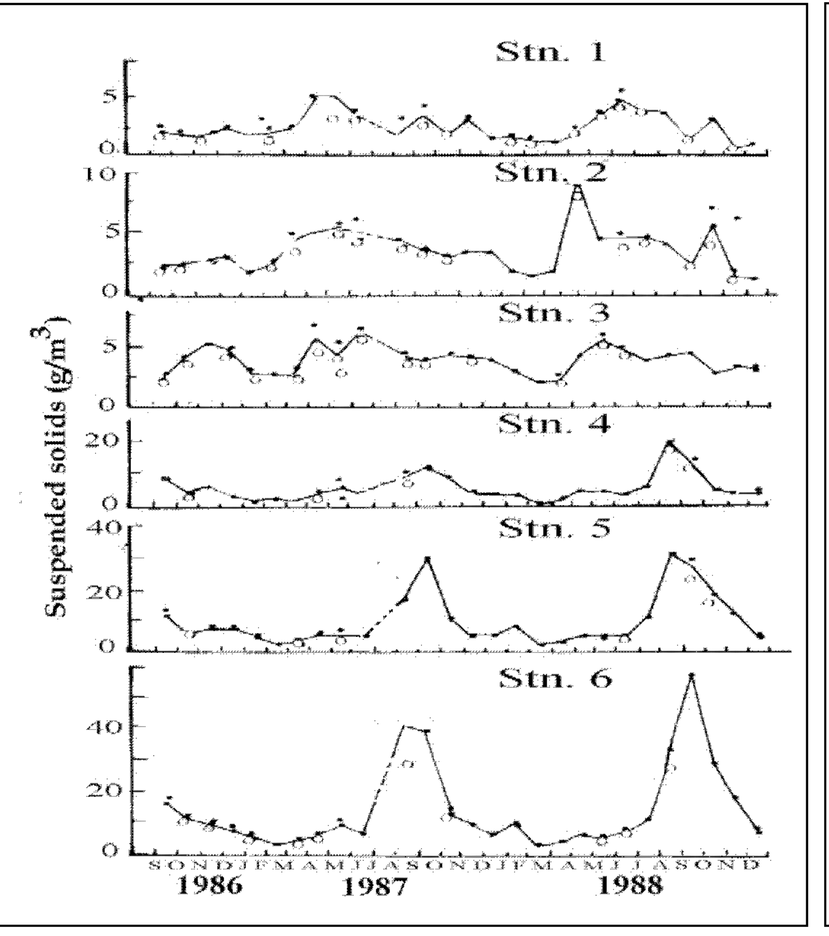


Fig. 42 **Seasonal changes of the suspended solids at stns. 1 - 6 in the main channel of Lake Nasser. Lines are for averages of the surface (○) and 2m (•) depth (Habib *et al.* 1996). [**For stations refer to Fig. 4**].**

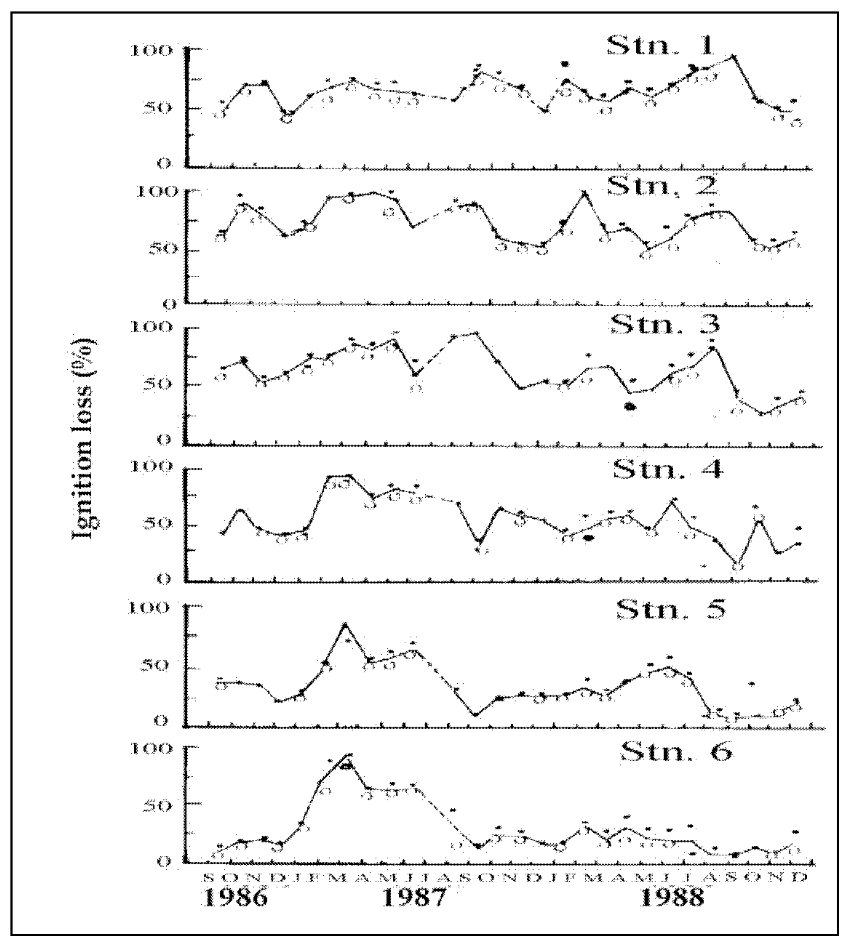


Fig. 43 **Seasonal changes of the ignition loss of suspended solids at stns. 1 - 6 in the main channel of Lake Nasser. Lines are for averages of the surface (○) and 2m (•) depth (Habib *et al.* 1996) [**For

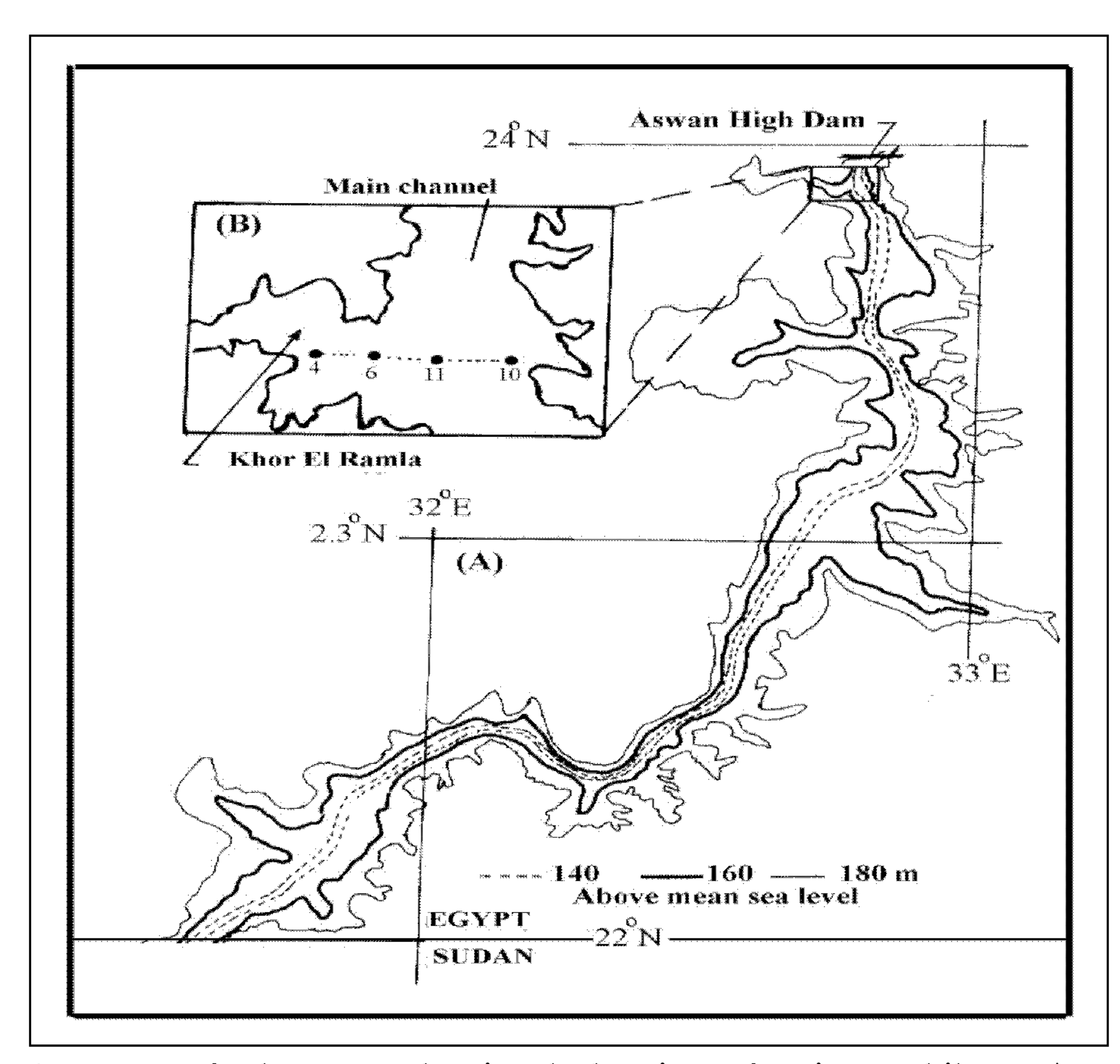


Fig. 44 **Map of Lake Nasser showing the locations of stations Habib 1995c).**

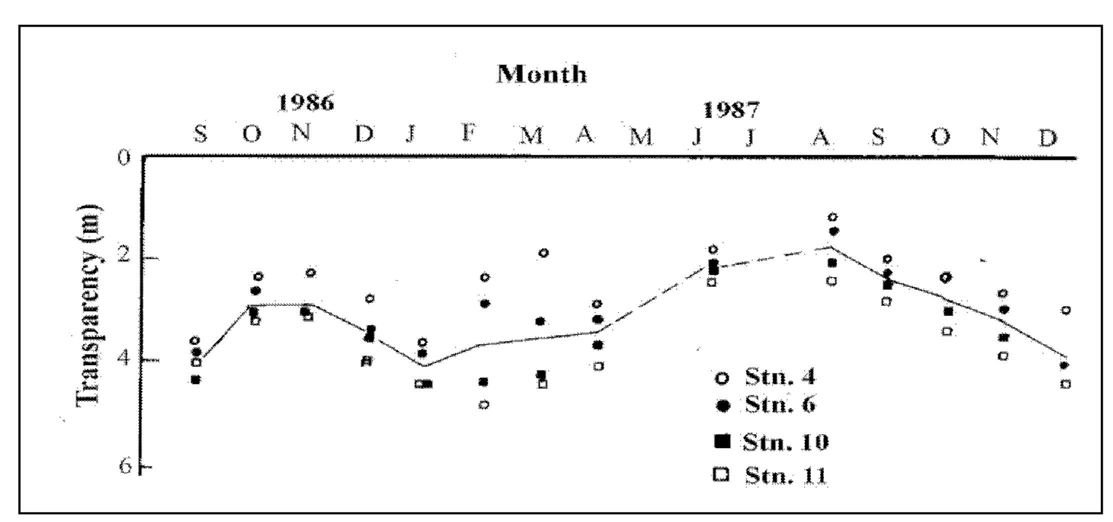


Fig. 45 **Seasonal changes of the transparency at stns. 4, 6, 10 and 11 in Khor El Ramla of Lake Nasser. The line is for averages of the four stations (Habib 1995c). [**For stations refer to Fig. 44**].**

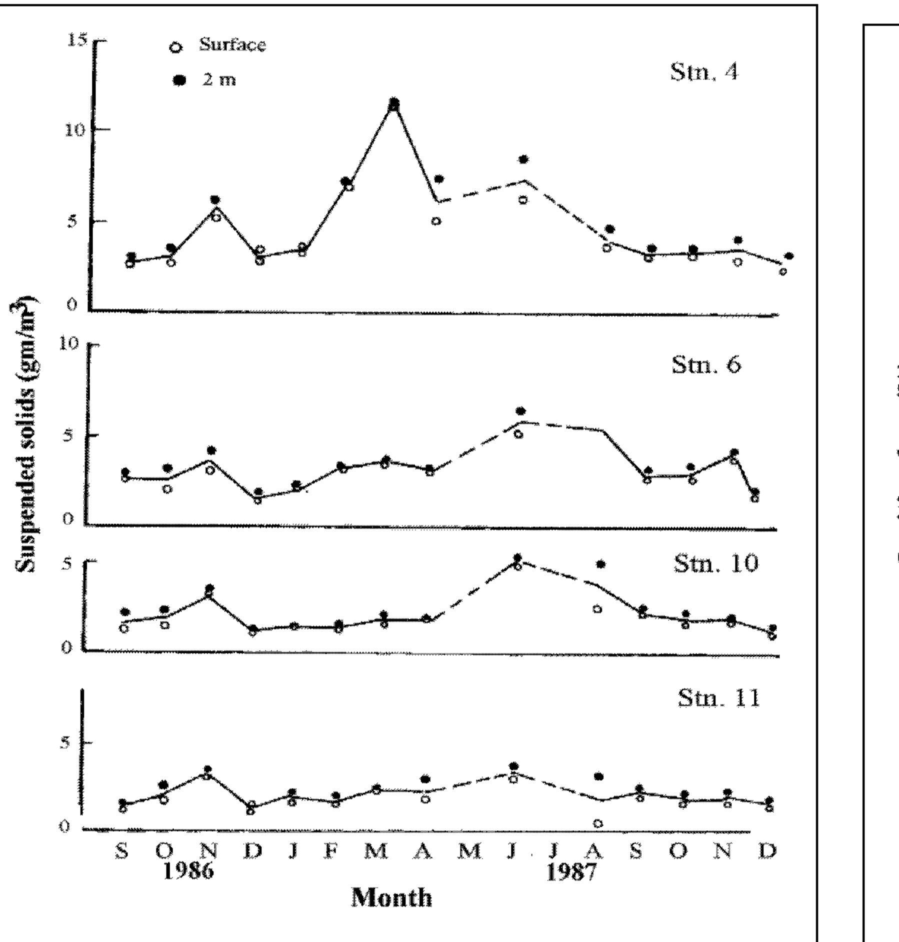


Fig. 46 **Seasonal changes of the suspended solids at stns. 4, 6, 10 and 11 in Khor El Ramla. Lines are for averages of the surface (○) and 2m (•) (Habib 1995c)** **[**For stations refer to Fig. 44**].**

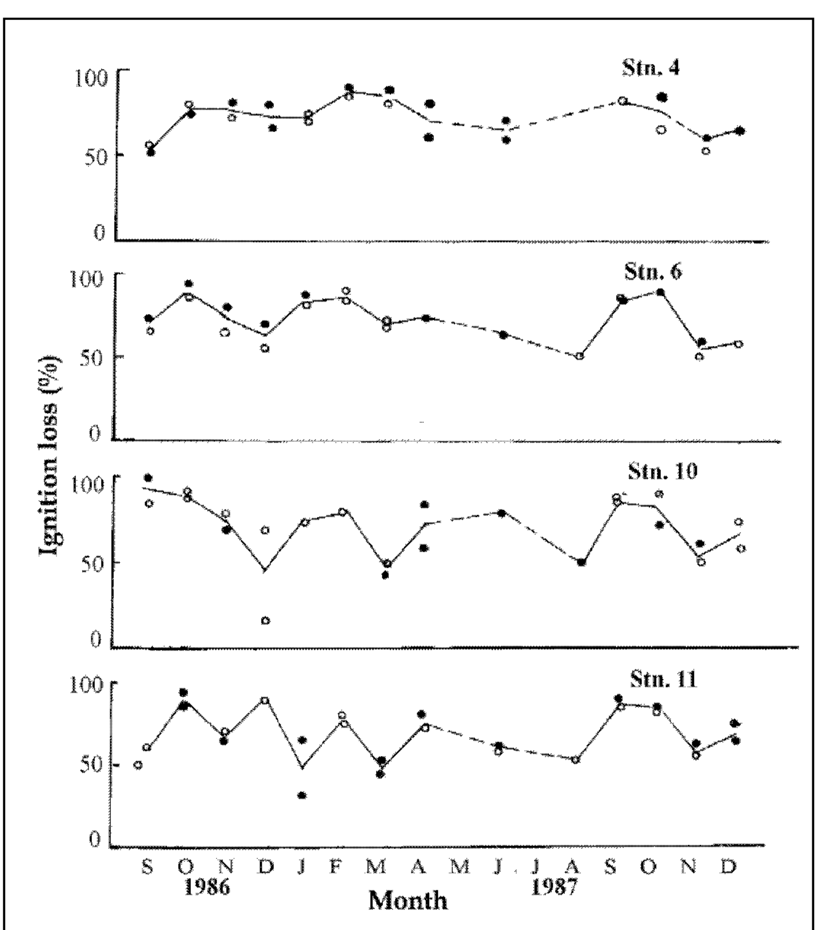


Fig. 47 **Seasonal changes of the ignition loss of suspended solids at stns. 4, 6, 10 and 11 in Khor El Ramla. Lines are for averages of the surface (○) and 2m (•) (Habib 1995c)** **[**For stations refer to Fig. 44**].**

Generally, the ignition loss was high (50 -95%) at stns. 4 and 6, and low (17 - 100%) at stns. 10 and 11 (Fig. 47). The patterns of seasonal changes of ignition loss were similar among stns. 4 & 6, and also among stns. 10 & 11. The suspended solids were significantly high during the flood season. The seasonal changes of the ignition loss were quite different from those of suspended solids. This suggests that there are great seasonal variations in the proportion of inorganic suspended solids to the total suspended solids or the particulate organic matter.

Mohamed, I. (1996a) mentioned that transparency in Khor El Ramla during 1990 had a maximum value of 5.3 m at stn. 10 in November, while the minimum value (1.1 m) was recorded at stns. 10 and 11 in May. Transparency was low during the period of high chlorophyll *a* concentration and high during the period of low chlorophyll *a* concentration. The latter author attributed the low transparency to the presence of phytoplankton as well as the suspended substances.

Table 28 **Monthly and mean annual variations of water colour (units) at six stations of Lake Nasser in 1983 and 1984 (in parentheses) (Goma & Abdel-Rahman 1992 a and b).**

Month	Stations						Monthly average
	1	2	3	4	5	6	
Jan.	15 (14)	14 (14)	15 (14)	14 (15)	14 (15)	17 (15)	14 (15)
Feb.	14 (14)	15 (14)	16 (14)	14 (14)	14 (14)	14 (14)	14 (14)
Mar.	14 (-)	14 (-)	15 (-)	14 (-)	14 (-)	14 (-)	14 (-)
April	14 (14)	15 (14)	14 (14)	14 (14)	14 (14)	13 (14)	14 (14)
May	15 (14)	16 (14)	15 (14)	14 (14)	15 (14)	14 (14)	14 (14)
June	14 (14)	14 (14)	14 (14)	13 (14)	15 (14)	15 (14)	14 (14)
July	14 (14)	14 (14)	14 (14)	14 (14)	14 (14)	14 (14)	14 (14)
Aug.	14 (14)	14 (14)	14 (14)	14 (14)	14 (15)	14 (14)	14 (14)
Sept.	14 (14)	15 (14)	14 (14)	14 (14)	15 (14)	15 (14)	14 (14)
Oct.	13 (15)	14 (15)	14 (15)	13 (14)	15 (15)	15 (14)	14 (15)
Nov.	14 (14)	14 (14)	14 (14)	15 (14)	15 (15)	15 (16)	14 (15)
Dec.	14 (14)	14 (14)	14 (14)	14 (14)	14 (15)	15 (15)	14 (14)
Mean annual	14	14	14	14	14	14	14

Apparent colour of the lake

Unit	1 - 2	3 - 4	5 - 7	8 - 10	11 - 15	16 - 19	20 - 22
Colour	Blue	Greenish blue	Bluish green	Green	Greenish yellow	Yellow	Brown

For stations refer to Fig. 4.

WATER COLOUR

Studies on the monthly and mean annual variations of water colour at six stations on Lake Nasser during 1983 and 1984 (Goma & Abdel-Rahman 1992a and b) showed, more or less, identical values (Table 28). Monthly variations ranged from a minimum of 13 units in October 1983 at station 1 to 17 units at station 6 in January 1983. In 1984, a maximum value (16 units) was recorded at the same station but in November. The water colour of the Lake is

mainly greenish yellow (14 units) in most stations and throughout the year. This might be attributed to the abundance of phytoplankton (Goma & Abdel-Rahman 1992b).

CONCLUSIONS

In warm and cold seasons surface water temperatures are not far from those of the air. The difference between surface and bottom temperatures in riverine environments is found to be slight, while the difference increases with impoundment. In Lake Nasser, the water columns are well mixed during winter, with almost homogenous temperature. A decrease in water temperature with depth of the Lake becomes clear in spring.

Thermal stratification becomes more prominent in summer time, with wide difference in temperature between surface and bottom at all stations of Lake Nasser and even during different years. The distruction of stratification in the Lake takes place in autumn and winter.

Transparency (Secchi disk reading) in Lake Nasser shows regional, seasonal and vertical variations. Secchi disk readings are highest during winter in the main channel (average 278.5 cm), showing a slight decrease in spring (average 252 cm). Slightly lower values are recorded in the eastern and western sides of the Lake. In summer (July - September) a sharp decrease in transparency throughout the entire Lake is recorded, which is attributed mainly to the arrival of flood water rich in suspended material. In autumn a slow increase of transparency occurs throughout the entire Lake.

The lowest transparency is recorded in the southernmost stations during flood. The ignition loss of suspended solids is high at the northern region and low at the southern. It seems that both eastern and western sides of the Lake are more turbid than the main channel. Furthermore there are great seasonal variations in the proportion of inorganic solids to the total suspended solids or to particulate matter.

In khors, the highest transparency is recorded in winter and reaches its minimum during flood. The southernmost khors are more turbid than the northern. Suspended solids are usually higher in khors compared with those in the main channel and sides of the Lake. Apparently the total suspended solids and phytoplankton play an important role in determining transparency of water (Secchi disk depth) of the Lake.

Under certain conditions, especially long lasting wind blowing from the shore, an upwelling current could be formed bringing water masses poor in plankton from deeper water to the surface, thus leading to exceptionally high transparencies, i.e. 7.4 m or more.

Chapter 4
Chemical Environment

OXYGEN CONTENT

The main channel

The oxygen concentration of Lake Nasser varies seasonally, vertically and horizontally, and in general, ranges between 3 and 12 mg/l for the surface water, and from 0 to 8 mg/l for the bottom waters (Latif 1984a). In winter and spring the water column is well oxygenated. The oxygen concentration shows a rapid increase in the upper water layers with an increase in water temperature in April, when values above 150 % or even 200 % saturation are recorded, but it exhibits regional and seasonal differences with depth (Entz 1976).

Elewa (1980) and Latif (1984a) point out that thermal stratification coincides with the formation of an oxygenated epilimnion and oxygen-free hypolimnion. They add that the depth of the oxygenated epilimnion becomes deeper southwards. Thus, in the northern part of Lake Nasser the oxygenated layer is 8 m deep compared with 20 m at Adindan. In the northern part of Lake Nubia, the epilimnion was 23 m deep, while the southern part was completely oxygenated from the surface to the bottom (Table 29, Fig. 48).

In autumn the drop in temperature is accompanied by the initiation of destruction of oxygen stratification or, in other words, a gradual increase in thickness of the oxygenated layer (Fig. 50). In winter, the whole water column becomes oxygenated and thus the oxygen concentration does not show great variation between surface and bottom waters, as it is the case in summer (Fig. 50). Thus, through a year, a single overturn takes place in winter.

It is worth mentioning that, the destruction of thermal and oxygen stratification starts with the incoming flood in the southern part of Lake Nubia and progresses northwards along its whole length and further to the southernmost part of Lake Nasser. Here, the epilimnion becomes thicker than that in the remaining northern part of the reservoir. The metalimnion is at 50 m

at Adindan (300 km from the High Dam) as compared with 25 m at Allaqi (100 km from the HD) and only 15 m in Khor El Ramla (9 km from the HD) in September 1970 (Entz 1976). Therefore, with the incoming flood in July 1974 (Fig. 49) the difference in temperature and oxygen content with depth becomes narrower up to the Second Cataract (near Wadi Halfa) than in the remaining northern part of the reservoir (Elewa 1980).

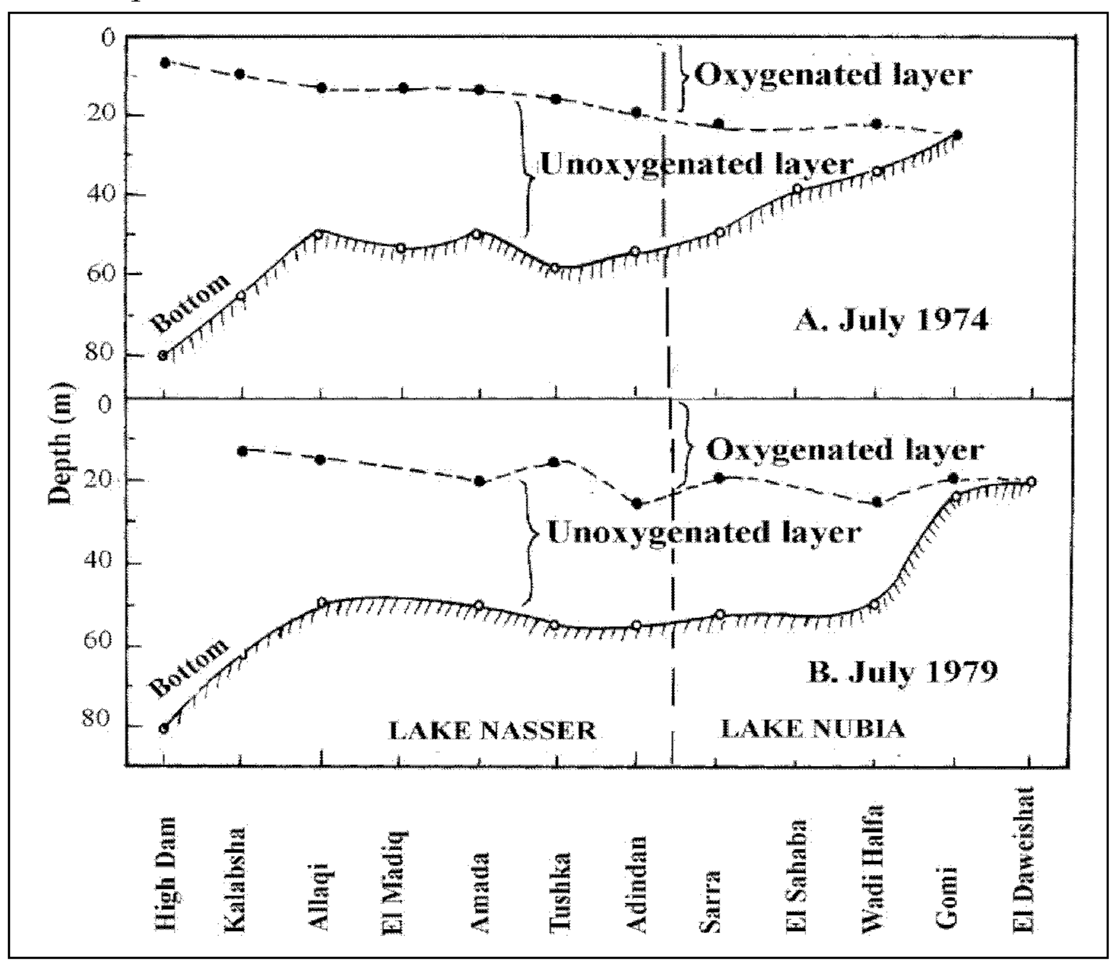


Fig. 48 **Depths of oxygenated and non-oxygenated layers along the main channel of the Aswan High Dam Reservoir in July 1974 and 1979 (Elewa 1980).**

Studies on the vertical and seasonal variations of the dissolved oxygen at six stations in Lake Nasser during 1985 (Abdel-Rahman & Goma 1992c) indicated that the water column was well oxygenated and was almost homogeneous from January to March (Fig. 51). During this period there were slight vertical variations of the dissolved oxygen, which may be related to difference in photosynthesis. The maximum value of dissolved oxygen was 8.3 ml/l (123.5 % saturation) at the surface layer at Abu Simbel in January. The minimum dissolved oxygen was 3.0 ml/l (43.5 % saturation) at the near bottom water layer at El Ramla. During the warm season, from May to August, the amount of dissolved oxygen showed significant vertical changes due to the summer stratification. There was a slight vertical variation of the dissolved

oxygen from September to December at all stations except September and October at station 1 (Elewa 1980).

Table 29 **Oxygenated layer and total depth (m) at different stations along the main channel of Lake Nasser and Lake Nubia in July, 1974 and 1979 (Latif 1984a).**

Site	Distance from HD (km)	Total Depth (m)	Depth (m) Oxygenated layer (epilimnion)	
			1974	1979
Lake Nasser				
High Dam	3	82	8	--
Kalabsha	50	63	10	13
Allaqi	100	50	13	15
El-Madiq	130	53	13	18
Amada	200	50	13	20
Tushka	250	60	16	15
Adindan	300	55	20	25
Lake Nubia				
Sarra	310	50	23	20
El-Sahaba	340	40	23	--
Wadi Halfa	360	35	23	25
Gomi	375	25	25	20
El-Daweishat	410	20	--	20
Melik El-Nasser	448	20	20	20 (riverine)

In their study on the vertical distribution of dissolved oxygen at El Ramla (station 1) (Fig. 52) and Abu Simbel (station 6) (Fig. 53), Abdel-Rahman & Goma (1993) recorded maximum concentrations of dissolved oxygen (7.2 ml/l) at 5 m depth at station 6 in April (Fig. 52) and 6.2 ml/l at the surface of station 1 in May (Fig. 53). From August to September complete oxygen depletion was recorded at El Ramla (station 1) at 30-60 m depth, being the same as that recorded in 1985. Also, at depths 40 m or more in October and 50 m depth or more in November. It is considered that the low oxygen water mass exerts a harmful influence on the aquatic fauna of Lake Nasser.

Considering the vertical and seasonal distribution of dissolved oxygen at six stations during the period 1987 - 1992 (Tables 30 - 35 and Fig. 54), the maximum concentration of dissolved oxygen (10 ml/l) was recorded in spring 1991 at 5 m depth at Kalabsha. Generally, high oxygen concentrations were recorded at all stations in spring 1987 - 1992, particularly in 1991 and 1990. Thus, the concentration of dissolved oxygen was very high in spring 1991: 10 ml/l (at 5 m), 9.9 ml/l (at 5 m) 9.9 ml/l (at 0 m); 9.4 ml/l (at 5 m); 9.3 ml/l (at 5 m) and 9 ml/l (at 5 m) at Kalabsha, Korosko, Abu Simbel, Tushka, Allaqi and El Ramla, respectively. Nearly, the same picture was observed in spring 1990, being 9.5 ml/l (at 5 m), 9.4 ml/l (at 0 m), 8.9 ml/l (at 0 m), 8.9 ml/l (at 5 m), 8.7 ml/l (at 5 m), 8.5 ml/l (at 0 m), at Kalabsha, El Ramla, Allaqi, Korosko, Tushka and Abu Simbel respectively. Generally, in winter, the whole water mass is well oxygenated and almost homogeneous (Fig. 54). However, there is a slight

variation of dissolved oxygen among the different depths in winter, and this is clearly observed at Kalabsha during 1991. Thus, the oxygen concentrations ranged between 7.9 and 8.2 ml/l at depths 80 to 0 m. A different picture was observed in summer (Fig. 53). Thus, moderate or high oxygen concentrations (4.1 - 8.7 ml/l) were recorded in surface water layers (0 - 5 m). With increase of depth, a sharp decrease in oxygen concentration was observed reaching 0 ml/l in bottom water layers. In different years and at different stations of Lake Nasser and during autumn, moderate and sometimes high concentrations of oxygen (3.7 - 9.1 ml/l) were recorded in the surface water layers. But, a slow decrease of oxygen concentration was observed with the increase of depth, sometimes reaching 0 ml/l in bottom layers.

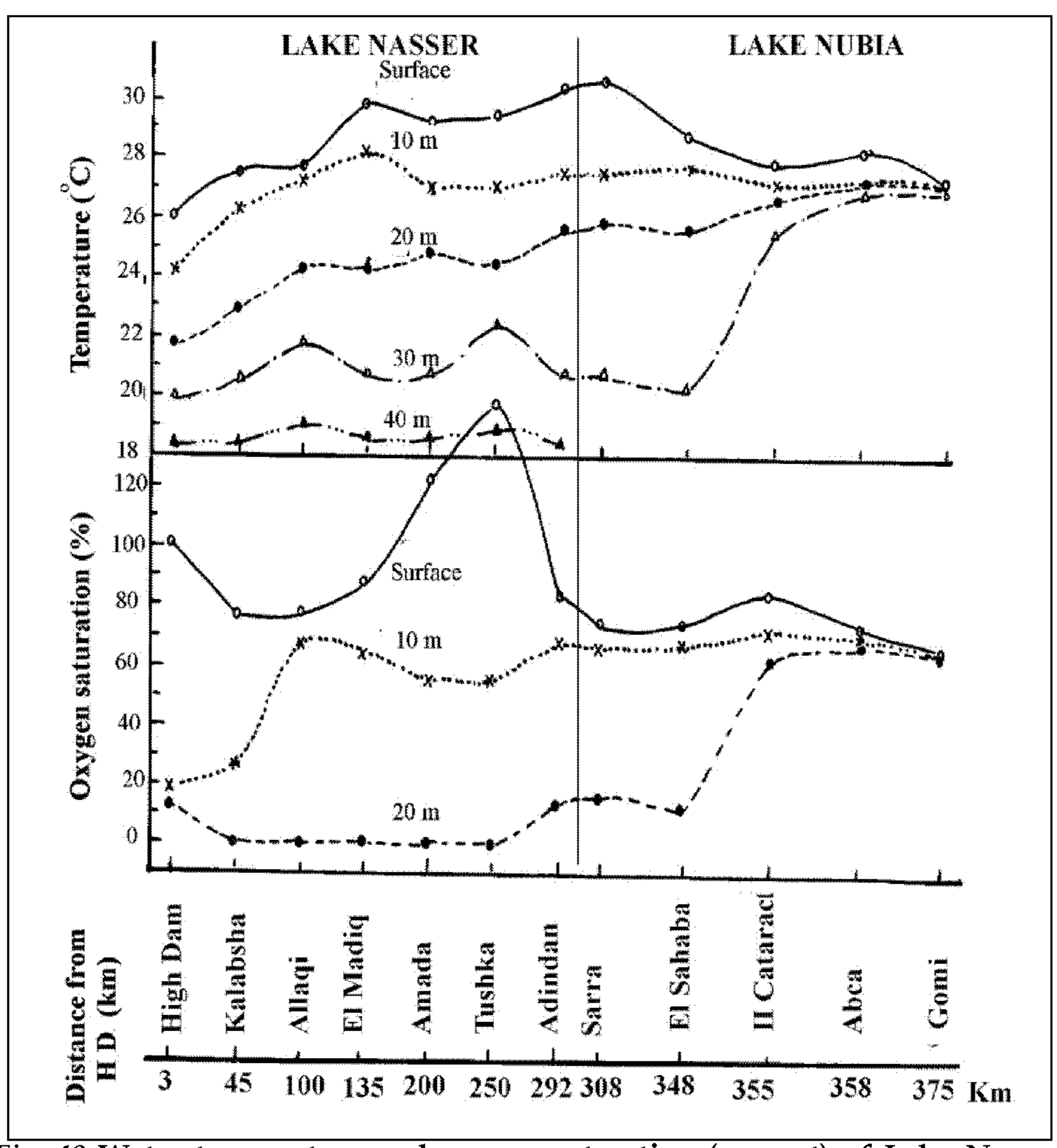


Fig. 49 **Water temperature and oxygen saturation (percent) of Lake Nasser and Lake Nubia during July 1974 (Elewa 1980).**

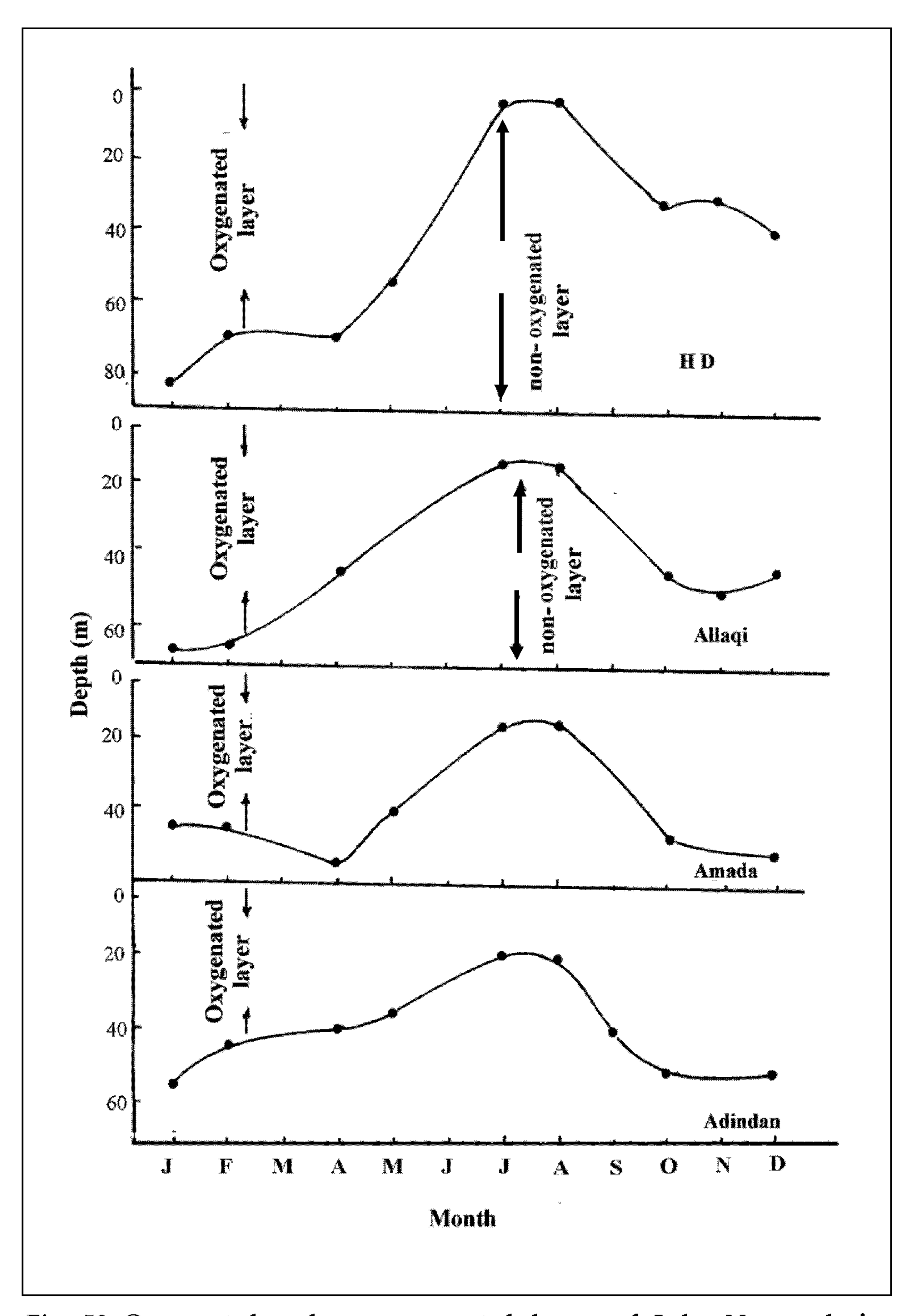


Fig. 50 **Oxygenated and non-oxygenated layers of Lake Nasser during different months of the year (Elewa 1980).**

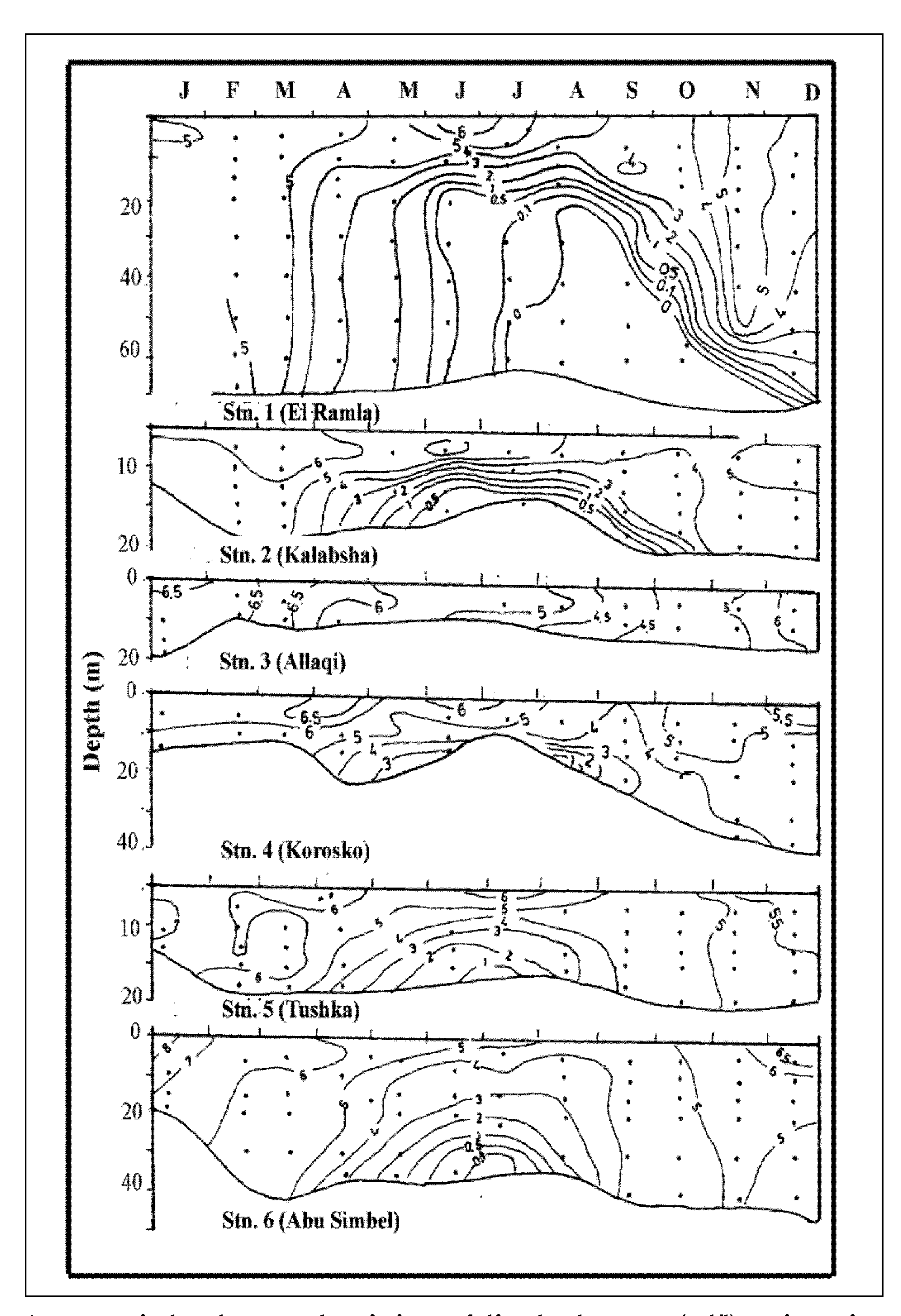


Fig. 51 **Vertical and seasonal variations of dissolved oxygen (ml/l) at six stations in Lake Nasser in 1985 (Abdel-Rahman & Goma 1992c) [**For stations refer to Fig. 4**].**

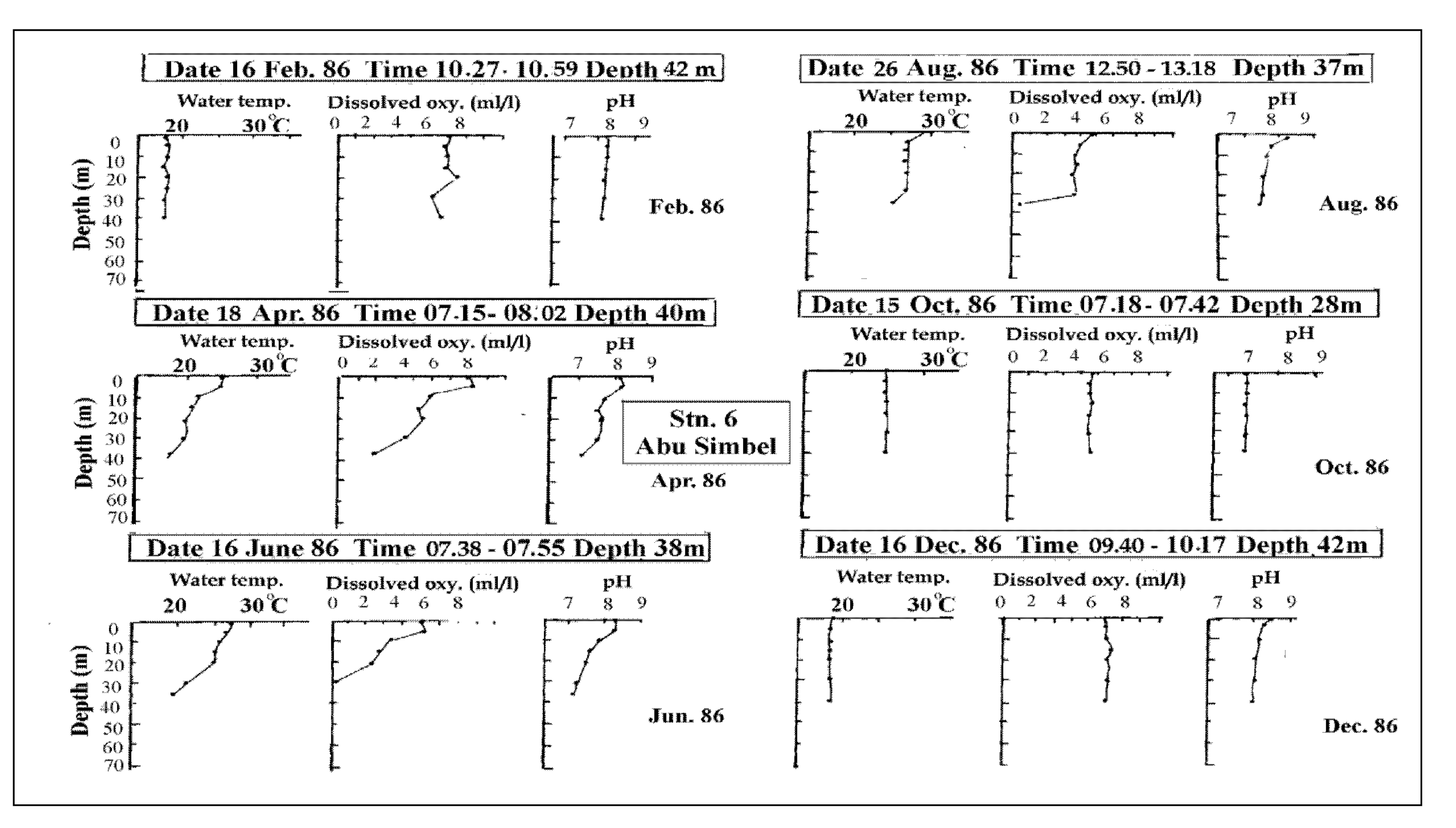


Fig. 52 **Vertical distribution of water temperature, dissolved oxygen and pH during February, April, June, August, October, and December 1986 at stn. 1 (El Ramla) in Lake Nasser (Abdel-Rahman & Goma 1993).**

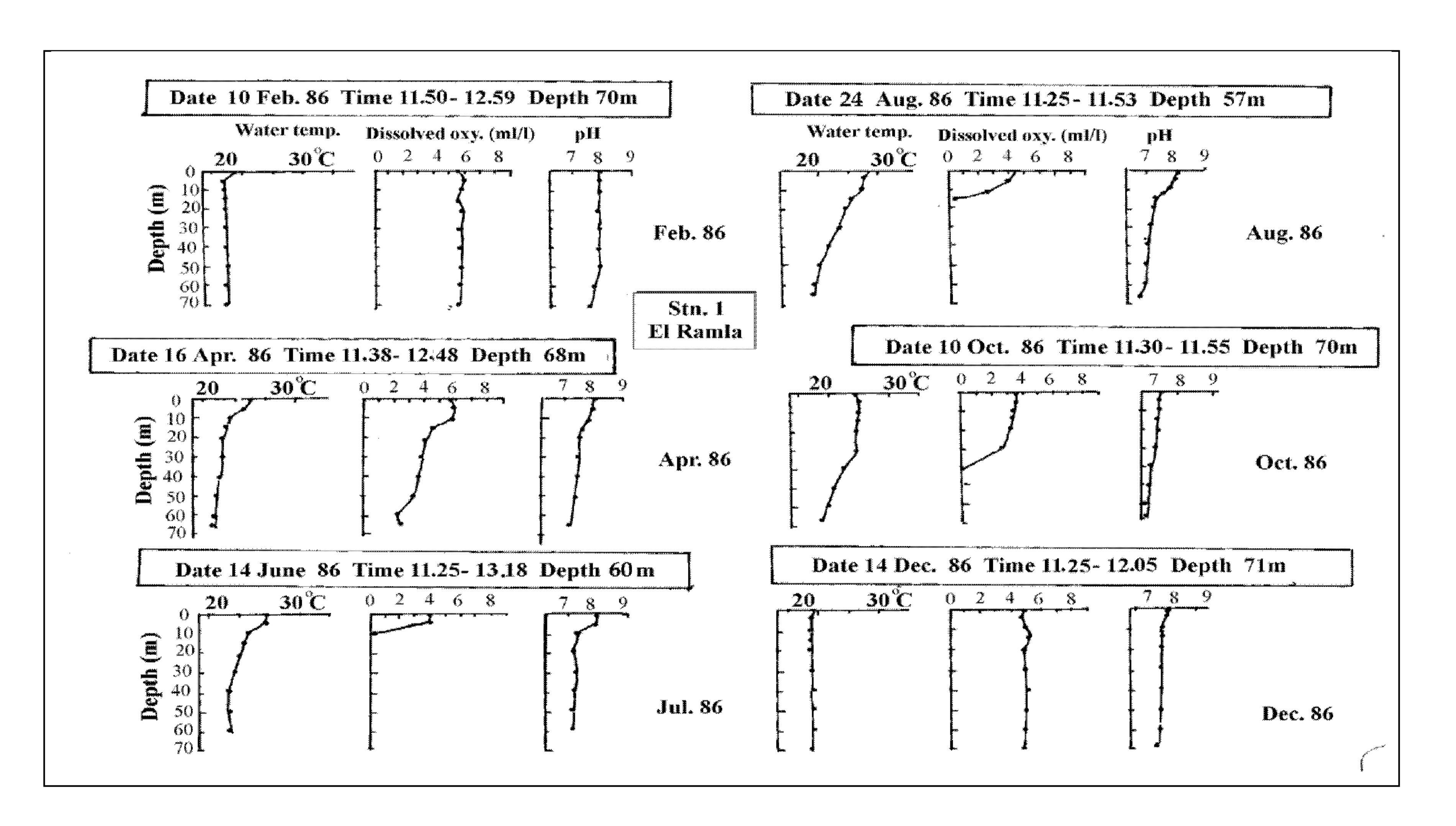


Fig. 53 **Vertical distribution of water temperature, dissolved oxygen and pH during February, April, June, August, October, and December 1986 at stn. 6 (Abu Simbel) in Lake Nasser (Abdel-Rahman & Goma 1993).**

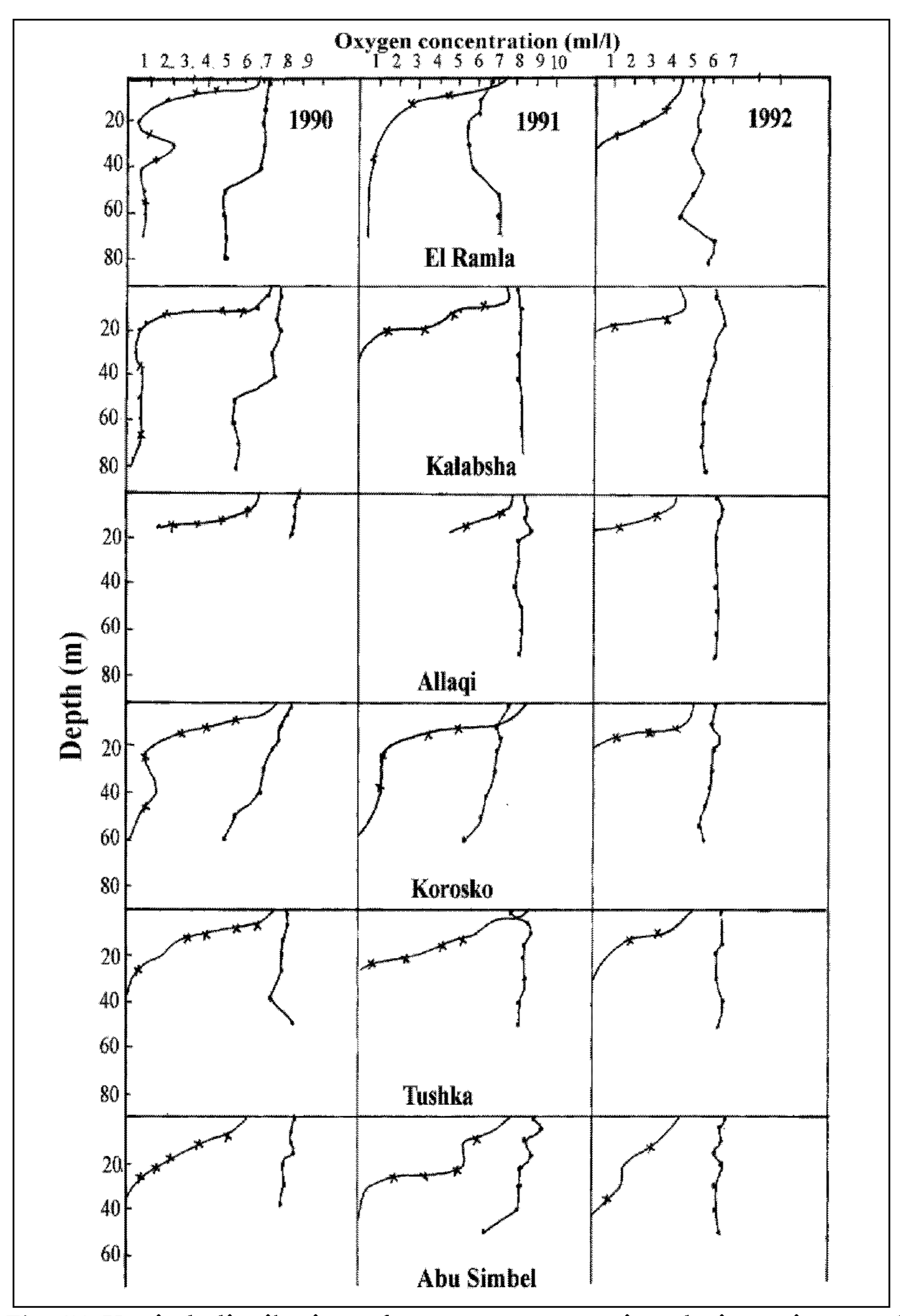


Fig. 54 **Vertical distribution of oxygen concentration during winter and summer (1990, 1991 and 1992) [•—• winter, x—x summer].(Abdel-Rahman & Goma 1993).**

Table 30 **Vertical and seasonal distribution of dissolved oxygen at El Ramla station (1987 - 1992).**

Depth (m)	1987*				1988*				1989*				1990*				1991**				1992**			
	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.
0	5.7	6.3	4.6	4.0	5.7	5.6	4.8	3.9	6.1	6.2	5.5	4.3	7.2	9.4	6.5	6.0	6.5	5.8	7.4	5.9	5.5	6.4	4.4	4.0
5	5.5	6.3	2.4	4.1	5.8	5.7	4.5	3.9	6.1	5.9	3.9	4.0	7.1	8.8	5.5	5.7	6.4	9.0	6.9	5.3	5.2	6.5	4.5	3.8
10	5.5	4.9	1.6	3.6	5.8	4.9	0.7	3.8	6.0	5.2	0.8	3.5	7.0	6.7	2.2	5.2	5.9	7.0	3.0	4.6	5.3	6.0	4.4	3.5
15	5.4	4.6	0.1	2.1	5.5	4.4	0.04	3.6	5.9	4.6	0.4	1.8	7.0	5.9	0.7	3.9	6.0	6.5	2.0	4.1	5.5	5.5	2.5	3.1
20	5.4	4.4	0	1.9	5.8	3.9	0.04	3.2	5.9	4.2	0.2	2.2	6.8	5.6	0.4	1.1	5.6	6.4	1.4	2.4	5.3	5.3	0	1.2
30	5.0	4.1	0	1.2	5.5	3.8	0.0	2.4	5.9	4.1	0.3	1.25	7.0	5.0	2.3	0	5.6	4.8	0.8	0.5	5.2	5.2	0	0.6
40	5.1	3.9	0	1.2	5.7	3.7	0.04	2.4	5.9	4.0	0.3	0.3	6.8	5.3	0.5	0	5.7	5.2	0.5	0	5.4	5.1	0	0
50	5.1	3.4	0	0.9	5.7	3.4	0.02	2.1	5.7	4.1	0.2	0	4.9	5.4	0.7	0	7.0	5.0	0.4	0	4.9	5.1	0.1	0
60	5.0	3.1	0	0	5.7	4.1	0.02	1.3	4.3	4.0	0.1	0	4.8	5.2	0.8	0	6.9	4.9	0.4	0	4.2	5.1	0	0
70	5.3	--*	0	0	4.4	--	--	--	4.3	4.0	0.0	0	5.0	4.9	0.7	0	7.0	5.0	0.4	0	6.0	4.8	0	0
80	--	--	--	--	--	--	--	--	--	--	--	--	5.0	--	--	0	--	--	0	0	5.6	4.2	0	0

***Abdel-Rahman & Goma (1995 a, b, c & d). **Abdel-Rahman (1995 a & b). For stations refer to Fig. 21. *(--) not recorded.**

Table 31 **Vertical and seasonal distribution of dissolved oxygen at Kalabsha station (1987 - 1992).**

Depth (m)	Dissolved oxygen (ml/l)																							
	1987*				1988*				1989*				1990*				1991**				1992**			
	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.
0	6.2	7.0	5.3	4.7	6.3	6.7	5.5	5.3	5.6	7.1	5.6	4.7	7.9	9.4	7.4	6.6	8.0	8.7	7.5	4.7	6.3	7.1	4.3	4.5
5	6.2	6.2	5.4	5.0	6.3	6.3	5.4	4.9	6.3	7.1	5.8	4.9	7.9	9.5	7.2	6.0	8.0	10.0	7.8	6.1	6.2	7.0	4.5	4.1
10	5.9	4.5	0.9	4.7	6.2	3.9	1.9	4.3	6.3	5.9	3.5	4.4	7.8	7.9	6.7	6.2	8.2	6.4	5.2	5.8	6.4	5.9	4.6	4.4
15	5.9	4.2	0.1	4.2	6.5	4.1	0.1	3.9	5.9	3.9	0.4	3.9	7.6	6.3	0.9	5.1	8.1	5.6	4.2	5.4	6.6	5.3	2.1	4.3
20	5.6	3.1	0	3.1	6.3	3.6	0.1	3.8	6.2	--	--	4.2	7.8	5.7	0.5	2.3	8.0	5.1	0.8	4.8	6.2	5.2	0	4.4
25	--	--	--	--	--	--	--	3.4	5.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	5.6	3.1	--	--	--	--	--	--	5.9	--	--	2.5	7.4	5.4	0.4	4.4	8.0	4.8	0	2.1	6.1	5.1	0	3.7
35	--	--	--	--	--	--	--	--	5.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
40	--	--	--	--	--	--	--	--	--	--	--	2.3	7.6	4.9	0.7	0	7.9	4.4	0	0	5.8	4.9	0	3.8
50	--	--	--	--	--	--	--	--	--	--	--	0	5.4	5.1	0.6	0	8.1	4.2	0.1	0	5.6	4.7	0	0
60	--	--	--	--	--	--	--	--	--	--	--	0	5.4	4.8	0.6	0	8.2	3.9	0.3	0	5.6	4.8	0	0
70												0	5.6	4.7	0.6	0	8.1	3.7	0.4	0	5.5	4.6	0	0

ertical and seasonal distribution of dissolved oxygen at Allaqi station (1987 - 1992).

Depth (m)	1987*				1988*				1989*				1990*				1991**				1992**			
	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.
0	6.4	6.7	5.0	4.9	6.7	6.6	5.1	4.6	6.4	6.6	5.1	4.8	8.8	8.9	6.7	7.0	8.4	9.2	7.7	7.1	6.2	6.8	4.1	3.7
5	6.3	7.1	5.1	5.2	6.7	6.6	5.2	4.7	6.5	6.9	4.9	4.8	8.6	8.8	6.6	7.2	8.5	9.3	7.7	6.7	6.5	6.9	3.0	4.5
10	6.3	5.1	2.4	5.0	6.7	5.8	3.1	4.7	6.6	6.0	2.4	5.3	8.6	7.6	5.5	7.3	8.3	7.5	6.3	6.4	6.3	6.5		3.4
15	6.3	--	--	4.7	7.0	--	--	4.6	6.5	4.9	0.7	4.6	8.5	6.5	1.6	7.1	8.7	7.0	4.4	6.5	6.2	5.8	0.0	2.2
20	--	--	--	--	7.0	--	--	--	7.1	4.5	--	--	8.3	--	--	--	8.0	--		5.8	6.1	5.7	0.0	0
30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.1	--	--	0.2	6.2	5.2	0.1	0
40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.8	--	--	0	6.2	5.1	0.1	0
50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.2	--	--	0	6.3	5.1	0.1	0
60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.2	--	--	0	6.2	4.9	0	0
70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.1	--	--	0	6.2	4.9	0	0

Table header: Dissolved oxygen (ml/l)

*Abdel-Rahman & Goma (1995 a, b, c & d). **Abdel-Rahman (1995 a & b). For stations refer to Fig. 21. *(--) not recorded.

Table 33 **Vertical and seasonal distribution of dissolved oxygen at Korosko station (1987 - 1992).**

Depth (m)	Dissolved oxygen (ml/l)																							
	1987*				1988*				1989*				1990*				1991**				1992**			
	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.
0	6.2	6.6	5.8	5.4	6.5	6.6	6.4	7.4	6.5	6.6	5.4	5.8	8.6	8.8	7.7	8.1	7.6	9.3	8.5	6.4	6.1	7.2	5.0	4.7
5	6.3	6.4	5.4	5.2	6.4	6.8	4.6	4.4	6.3	7.0	5.1	5.5	8.3	8.9	7.4	7.9	7.3	9.9	8.3	8.3	6.0	7.1	5.0	3.9
10	6.1	4.4	0.6	4.9	5.8	6.1	3.8	4.1	5.9	5.9	2.0	3.7	7.9	7.9	4.6	6.1	6.9	7.3	7.6	7.4	6.0	6.4	4.6	2.9
15	5.8	4.4	0.3	4.7	6.1	5.3	1.8	4.1	5.8	5.7	1.6	3.0	7.9	6.8	1.8	5.2	7.2	6.4	2.5	5.4	6.4	5.7	3.0	3.5
20	5.4	4.0	0	2.7	5.4	4.3	0.6	4.1	6.0	4.5	1.0	3.1	7.5	6.1	0.8	5.2	7.0	5.8	1.2	4.2	6.1	5.4	0.1	0
30	5.3	3.7	--	--	5.6	4.0	0.3	4.2	5.6	5.4	0.4	3.0	7.0	5.6	1.3	3.0	6.9	4.5	1.2	5.1	6.0	5.1	0.0 4	0
40	5.2	--	--	--	5.6	--	--	--	6.3	4.2	0	2.1	6.8	5.6	1.6	1.9	6.4	4.7	1.1	4.4	5.9	5.2	0.2	0
50	5.3	--	--	--	--	--	--	--	--	--	--	0.6	5.5	4.6	0.5	0	6.1	4.4	0.6	1.6	5.5	4.9	0	0
60	--	--	--	--	--	--	--	--	--	--	--	0.2	5.0	--	0.2	0	5.3	3.5	0	0	5.5	4.8	0.1	0
70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	0	0	--	--	0	0
80	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	--	--	--	--

***Abdel-Rahman & Goma (1995 a, b, c & d). **Abdel-Rahman (1995 a & b). For stations refer to Fig. 21. *(--) not recorded.**

Table 34 **Vertical and seasonal distribution of dissolved oxygen at Tushka station (1987 - 1992).**

Depth (m)	1987*				1988*				1989*				1990*				1991**				1992**			
	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.
0	6.3	6.9	4.8	5.0	6.5	6.4	5.4	4.7	6.6	6.6	5.4	5.6	8.3	8.4	7.8	7.1	7.7	9.2	8.7	9.1	6.4	7.2	5.0	5.1
5	6.3	6.3	4.7	4.8	6.5	6.4	3.9	4.6	6.6	6.3	5.1	4.8	8.3	8.7	7.3	6.8	8.6	9.4	6.5	6.7	6.6	7.0	4.4	4.2
10	6.2	5.2	3.8	4.7	6.4	5.6	2.6	4.6	6.5	5.8	3.2	4.5	8.2	8.2	4.6	6.6	8.7	7.6	6.2	6.7	6.5	6.6	3.7	3.9
15	6.0	4.5	2.4	4.7	6.1	4.8	2.3	4.7	6.5	5.3	3.2	4.5	8.1	7.9	2.2	6.5	8.4	6.3	4.4	6.7	6.5	5.9	1.0	3.9
20	6.0	4.4	0.1	4.6	6.0	4.8	1.8	4.6	6.5	5.0	2.0	4.5	8.0	6.4	1.8	6.0	8.4	6.0	3.0	7.7	6.2	5.3	0.7	0.7
30	6.0	--	--	--	5.9	--	--	4.5	6.4	4.4	0.3	4.6	8.1	6.2	0.2	4.3	8.5	4.6	0.1	6.4	6.2	5.2	0.1	0
40	--	--	--	--	--	--	--	--	--	--	--	3.7	7.7	5.9	0.1	1.6	8.2	3.4	0.1	5.2	6.5	4.8	0.1	0
50	--	--	--	--	--	--	--	--	--	--	--	2.0	8.6	4.7	0.1	0.2	8.1	2.7	0	3.4	6.4	4.3	0.1	0
60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	0	0	--	--	--	0
70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	--	--	--	--
80	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	--	--	--	--

Dissolved oxygen (ml/l)

***Abdel-Rahman & Goma (1995 a, b, c & d). **Abdel-Rahman (1995 a & b). For stations refer to Fig. 21. *(--) not recorded.**

Table 35 **Vertical and seasonal distribution of dissolved oxygen at Abu Simbel station (1987 - 1992).**

Depth (m)	1987*				1988*				1989*				1990*				1991**				1992**			
	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.	Wint.	Spr.	Sum.	Aut.
0	6.5	7.6	5.7	5.3	6.5	6.1	4.6	4.9	6.8	6.7	4.8	5.1	8.7	8.5	7.4	7.6	8.9	9.9	7.9	6.7	6.7	7.2	4.6	5.3
5	6.6	6.1	4.7	4.7	6.4	6.0	3.9	4.9	6.9	6.5	4.7	5.1	8.6	8.2	7.0	7.1	9.2	8.7	6.9	6.7	6.5	6.9	4.1	4.4
10	6.3	4.7	2.9	4.4	6.4	5.1	2.8	4.9	6.9	5.5	3.6	5.0	8.5	8.1	4.9	7.0	8.4	6.9	5.3	7.0	6.5	6.4	3.5	4.0
15	6.3	4.7	2.5	4.8	6.5	5.0	2.5	4.9	6.9	5.4	3.3	4.9	8.6	7.1	2.9	6.7	8.9	6.8	5.3	7.2	6.1	6.1	2.5	3.9
20	6.2	4.7	1.6	4.7	6.4	4.9	1.5	4.9	6.9	4.6	2.8	4.8	8.1	6.9	2.0	6.3	8.4	6.5	5.3	6.8	6.5	6.0	1.5	0
30	6.1	4.2	0.2	4.6	6.2	3.5	0.6	5.0	6.9	--	--	4.8	8.2	5.8	0.3	4.3	8.2	4.6	0.5	6.7	6.2	5.2	1.5	0
40	5.9	--	--	--	6.2	--	0	--	--	--	--	4.5	8.1	5.5	0.1	2.2	8.2	3.5	0.1	6.3	6.2	4.8	0.2	0
50	--	--	--	--	--	--	0	--	--	--	--	--	--	4.9	0.1	2.0	6.3	--	0	3.6	6.4	4.3	--	0
60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	0	0	--	--	--	0
70	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	0	0	--	--	--	--

Dissolved oxygen (ml/l)

***Abdel-Rahman & Goma (1995 a, b, c & d). **Abdel-Rahman (1995 a & b). For stations refer to Fig. 21. *(--) not recorded.**

Fishar (1995) estimated the dissolved oxygen in Lake Nasser during 1993 in the eastern side, main channel and western side and his results showed differences in the three regions. The oxygen profiles were, more or less, homogeneous in the bottom water and varied from 5.86 to 7.47 mg /l in the eastern stations, and from 2.31 to 3.66 mg/l at the main channel stations and from 5.67 to 8.18 mg/l in the western stations. Amada and Abu Simbel sections sustained the highest oxygen concentration, where the same value of 6.03 mg/l was recorded for each station. The seasonal variations of dissolved oxygen in Lake Nasser during 1993 (Fig. 55) indicate that in the bottom water, the dissolved oxygen attained their maximum values during spring (aggregates of 7.55, 7.22 and 8 mg/l for the eastern side, main channel and the western side respectively). On the other hand, the lowest concentrations of dissolved oxygen for the entire Lake were recorded in autumn and summer, where aggregate values were 4.71 and 4.68 mg/l respectively.

Khor El Ramla

Goma & Abdel-Rahman (1996) studied the dissolved oxygen variations in Khor El Ramla during 1985 - 1989. The surface waters (0 - 5 m depth) were well oxygenated all the year round and during the period of study. From January to April, the dissolved oxygen content was high (4 - 6 ml/l) in the whole water mass of Khor El Ramla. In May, of almost all years, the dissolved oxygen concentration started to decrease in the water layer below 10 m depth. In summer stratification period (June - September) the dissolved oxygen concentration ranged between 3 and 5 ml/l followed by lower values (0 - 3 ml/l) in the metalimnion layer (5 - 20 m depth) and the dissolved oxygen disappeared from the deepest waters. In October, the dissolved oxygen had a similar trend as in the summer period, but the thickness of metalimnion depth varied from 5 to 40 m in different years. The oxygenated water mass increased gradually in November, until the whole water mass became reoxygenated in December.

Comparing Lake Nasser with Lake Volta the level of oxygen saturation in the latter is mainly influenced by the wind. Because of the relatively low assimilation intensity and the strong dissimilation processes (the bottom is covered with decomposing trees, bush, grass or soil with high organic matter content, etc.) there is still continuing reduction in the oxygen taking place in the water mass as a whole. Consequently, oxygen supersaturations seldom occurred, and when they occur they are slight. The values were usually 80 - 95 % of the air saturation level at the surface. Oxygenation through the surface was found to be the main source of dissolved oxygen for Lake Volta. During completely calm weather a slow decrease in the amount of dissolved oxygen was observed during daytime. As an oxygen-increasing factor wind plays an unusually important role. Because of only slight temperature differences between surface and bottom, wind of a speed of 4-5 m/sec., blowing for one hour, could cause the oxygen content in Volta Lake to be increased by 0.45 mg/l, down to 40, 50 or 55 m. This would be the equivalent of about 70 g O_2/m^2 in the total water column.

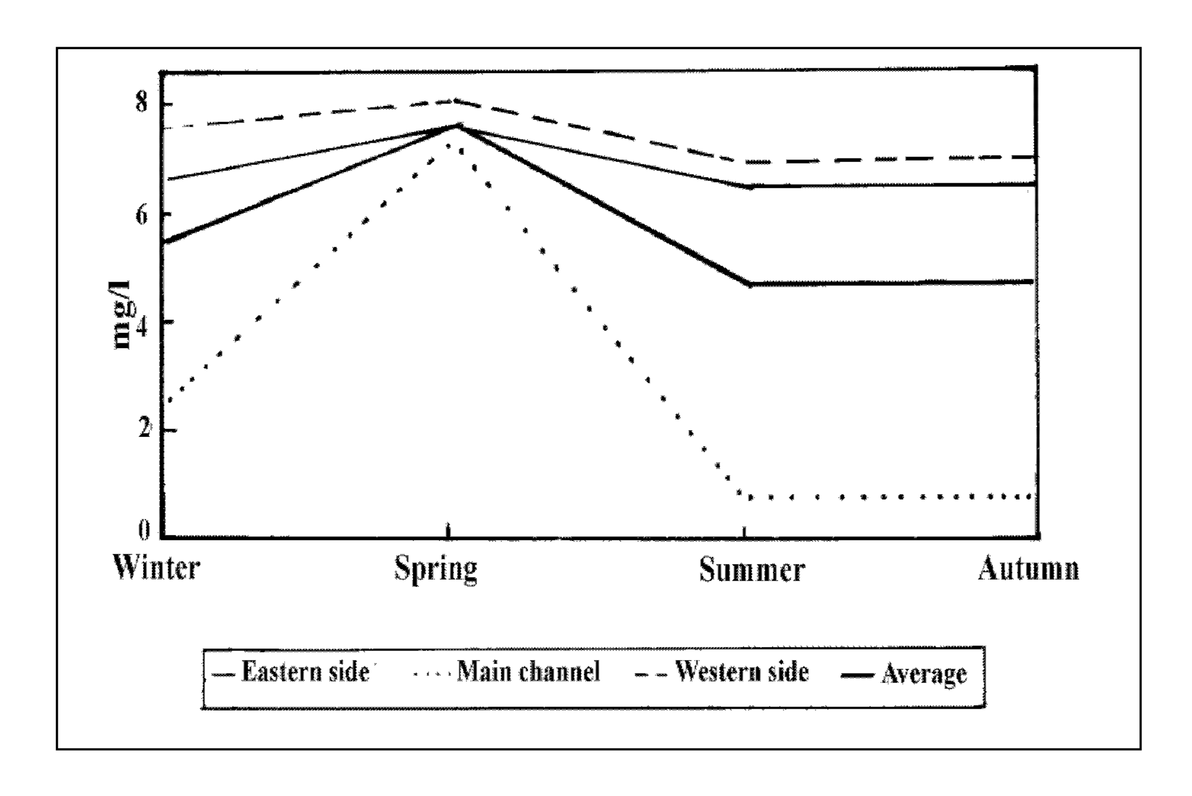


***Fig.** 55* **Seasonal variations of dissolved oxygen in Lake Nasser during 1993 (Fishar 1995).**

ELECTRICAL CONDUCTIVITY

Entz (1974b) and El-Shahawy (1975) pointed out that the variation in electrical conductivity in Lake Nasser follows, to a certain extent, the movement of water masses of the flood water. The highest conductivity values were recorded just in front of the flood water. El-Shahawy (1975) explained that the low conductivity of the Lake water during the flood period is due to the low water conductivity of the flooded Blue Nile which contributes about 84 % of the Nile flood. So, variations in conductivity in Lake Nasser can be taken as an indication of the movement of the water masses in the Lake. Entz (1976) pointed out that in 1970 the electrical conductivity of the Lake ranged between 235 and 290 µmhos cm^{-1} and suggested that on the basis of conductivity values it took about six months, for the front of the flood to pass through Lake Nasser from Adindan to the High Dam. Elewa (1980) studied the conductivity along the main channel of Lake Nasser for the surface and 50 m depth in different seasons in 1978. The latter author recorded values ranging from 190-245, 210-252, 210-228, 199-245 µmhos cm^{-1} for surface waters in winter, spring, summer and autumn respectively (Fig. 56), denoting the prevalence of lowest maximum in summer. In winter and spring, conductivity generally decreases southwards but in summer, the value showed gradual decrease from HD to Amada, but increased at Tushka, which had values comparable to that of Adindan

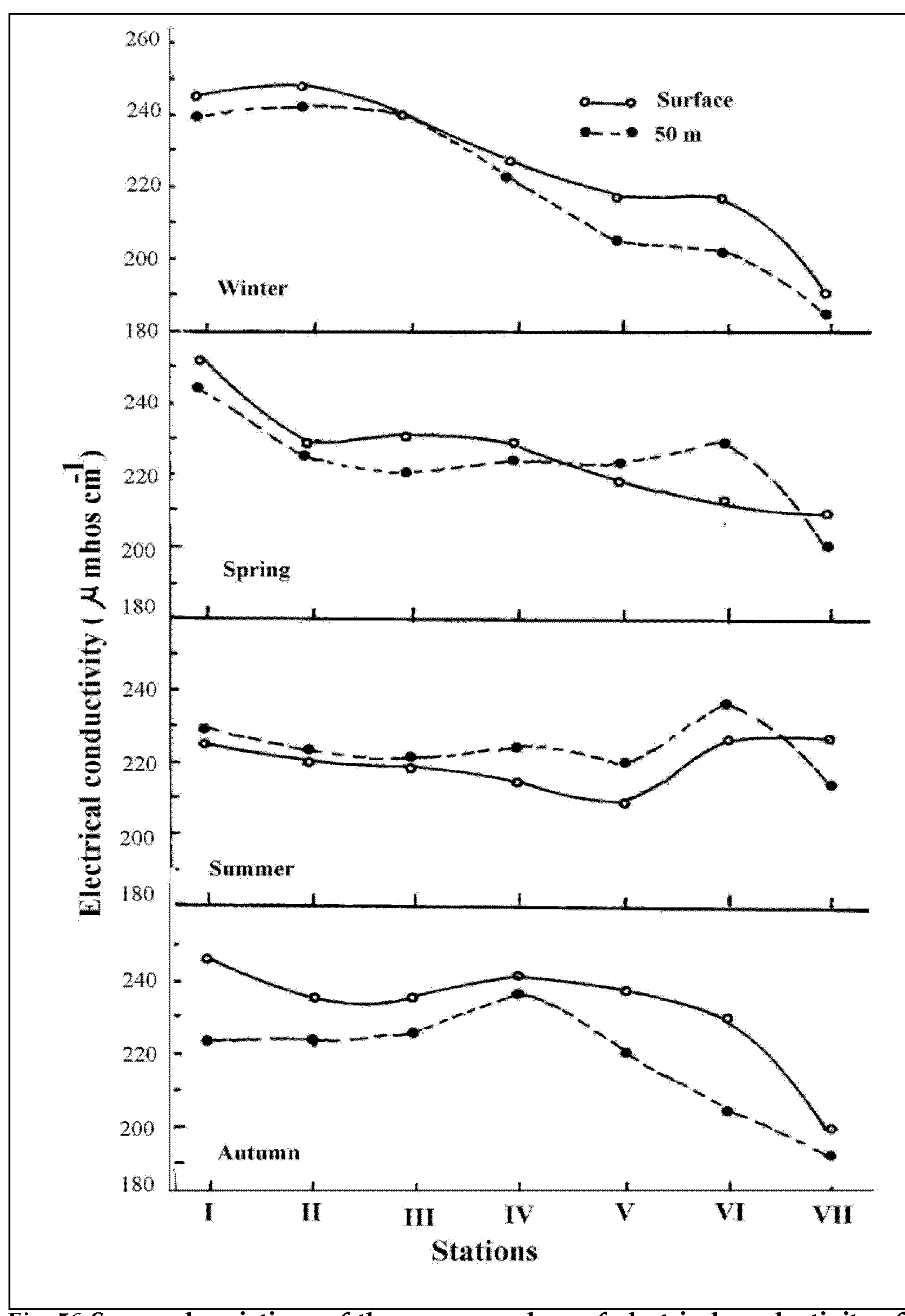


Fig. 56 **Seasonal variations of the average values of electrical conductivity of Lake Nasser at the surface and 50 m depth in different stations (Elewa 1980) [**For stations refer to Table 18**].**

(227 μmhos cm^{-1}). In autumn, the conductivity of surface water decreased from HD to Kalabsha but increased southwards to El-Madiq (240 μmhos cm^{-1}) which was followed by a gradual decrease to Tushka (229 μmhos cm^{-1}) and greater decrease at Adindan (199 μmhos cm^{-1}). In addition, the conductivity of deep water (50 m depth) had lower values than the surface water in winter and autumn and the difference is usually greater in the latter season (Fig. 56)

Latif (1984a) mentioned that the flood water usually pushes masses of water of relatively high electrical conductivity in front of it, thus appearing at different localities of Lake Nubia and the southern part of Lake Nasser at different times after the inception of the flood (Fig. 56). Later on, the electrical conductivity becomes lower in the flood affected region. Hence, the conductivity ranges from the surface to bottom at Adindan (300 km from the High Dam) was 242-260, 185-190, 195-185 and 196-171 μmhos cm^{-1} in July, November, January and April respectively, as compared with 241-235, 215-202, 220-200 and 215-228 μmhos cm^{-1} at Tushka (235 km from the HD) and 207-227, 235-225, 225-515 and 237-222 μmhos cm^{-1} at El-Madiq (140 km from the H D) (Latif 1984a).

Nour El-Din (1985) showed that the relative decrease in the electrical conductivity values in winter and spring of 1983 and 1984 were in good concordance with those of temperature during the same seasons. This might be principally attributed either to the uptake of dissolved salts by phytoplankton, as a result of upwelling and continuous mixing of water column, or to the lack of soluble salts in the region as a result of sedimentation or adsorption by silt.

Abdel-Monem (1995), recorded the highest conductivity value in 1993 (299 μmhos cm^{-1}) during winter at the bottom of Mariya site, and the lowest value (173 μmhos cm^{-1}) during spring at the bottom of Adindan site. It seems that Lake Nasser can be classified among lakes with moderate conductivity hence the predominant zooplankters are typically planktonic species. Morales-Baquero *et al.* (1989) pointed out that low conductivity lakes yielded greater densities of typical planktonic species, while high conductivity lakes contained predominantly benthic and periphytic species.

The values of electrical conductivity of some **khors** fluctuate between 155 μmhos cm^{-1} (in bottom waters of Khor Kalabsha) and 290 μmhos cm^{-1} (in surface water of Khor El Ramla). A marked increase of electrical conductivity values of the khors surface waters was observed from south to north (Gindy 1991 - Figs. 58 and 59).

At Khor Tushka, the inflow of flood from the south lowers the electrical conductivity due to the precipitation of the suspended matter leaving the water nearly free of electrical minerals containing ionic salt (Elewa 1987a).

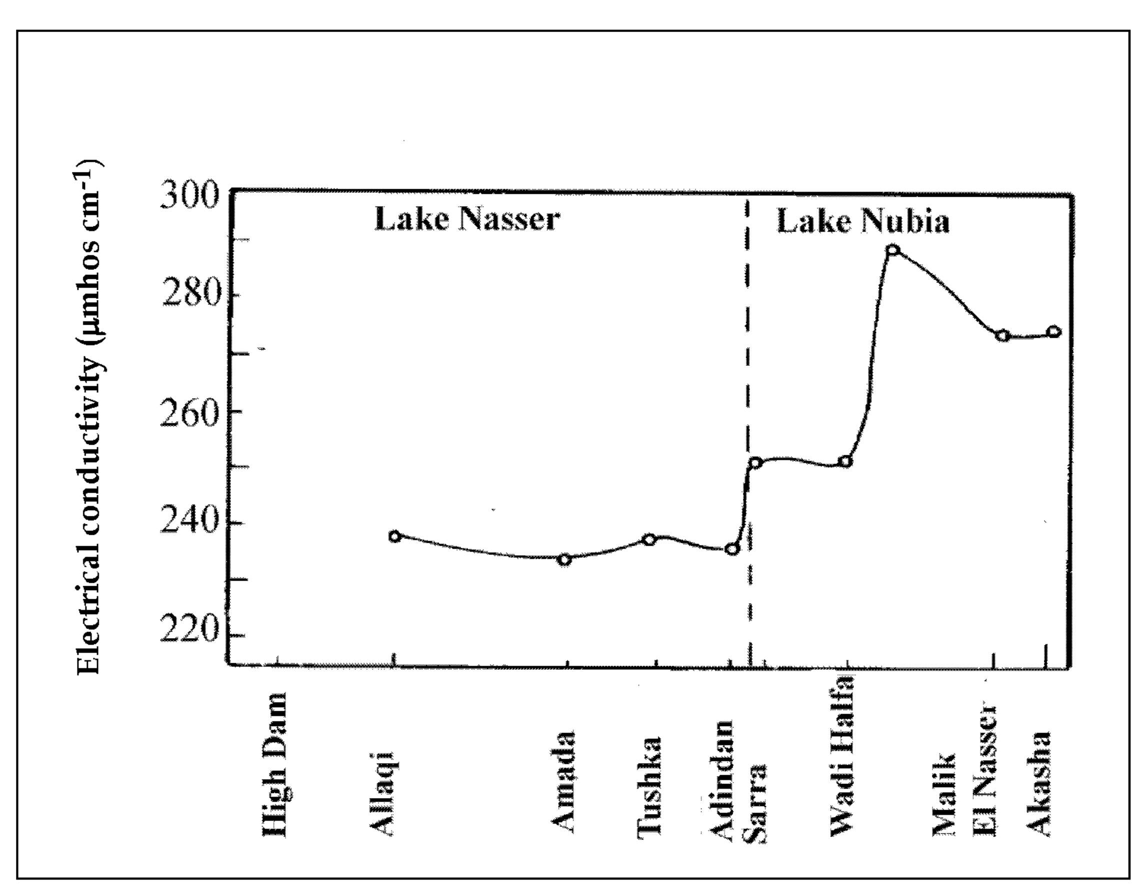


Fig. 57 **Electrical conductivity (µmhos cm^{-1}) of Lake Nasser and Lake Nubia in July/August 1976 (Latif 1984a).**

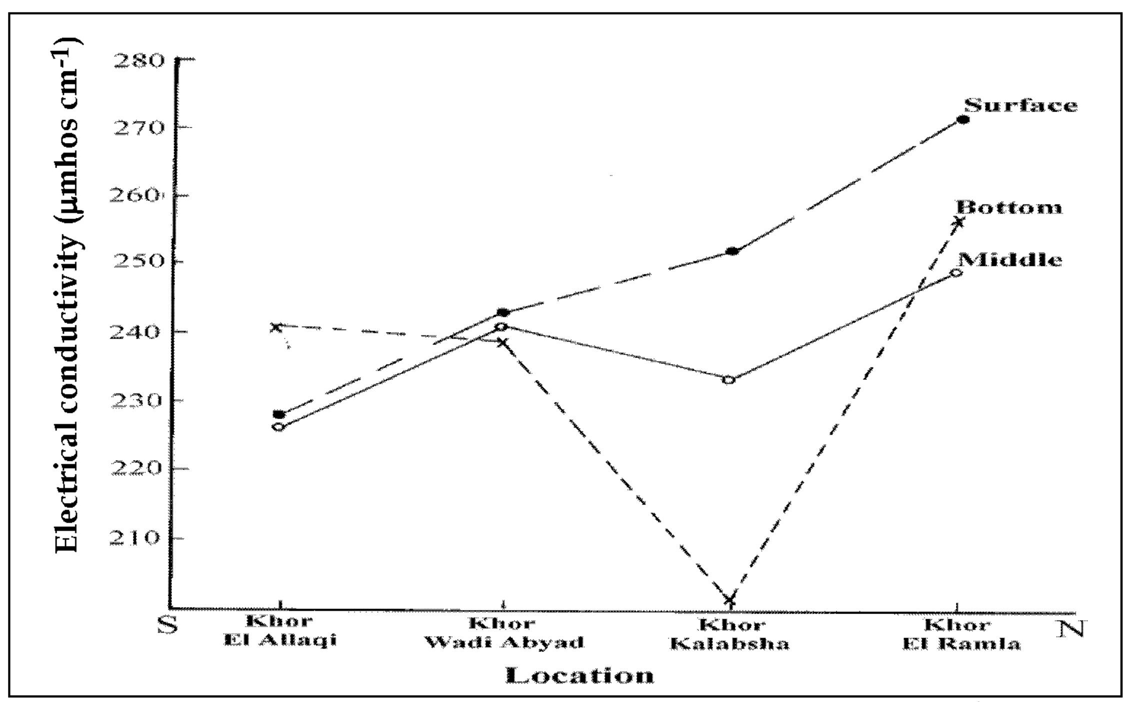


Fig. 58 **Average distribution of electrical conductivity (µmhos cm^{-1}) at various khors at Lake Nasser (June, 1987) (Gindy 1991) [**For stations refer to Fig. 59**].**

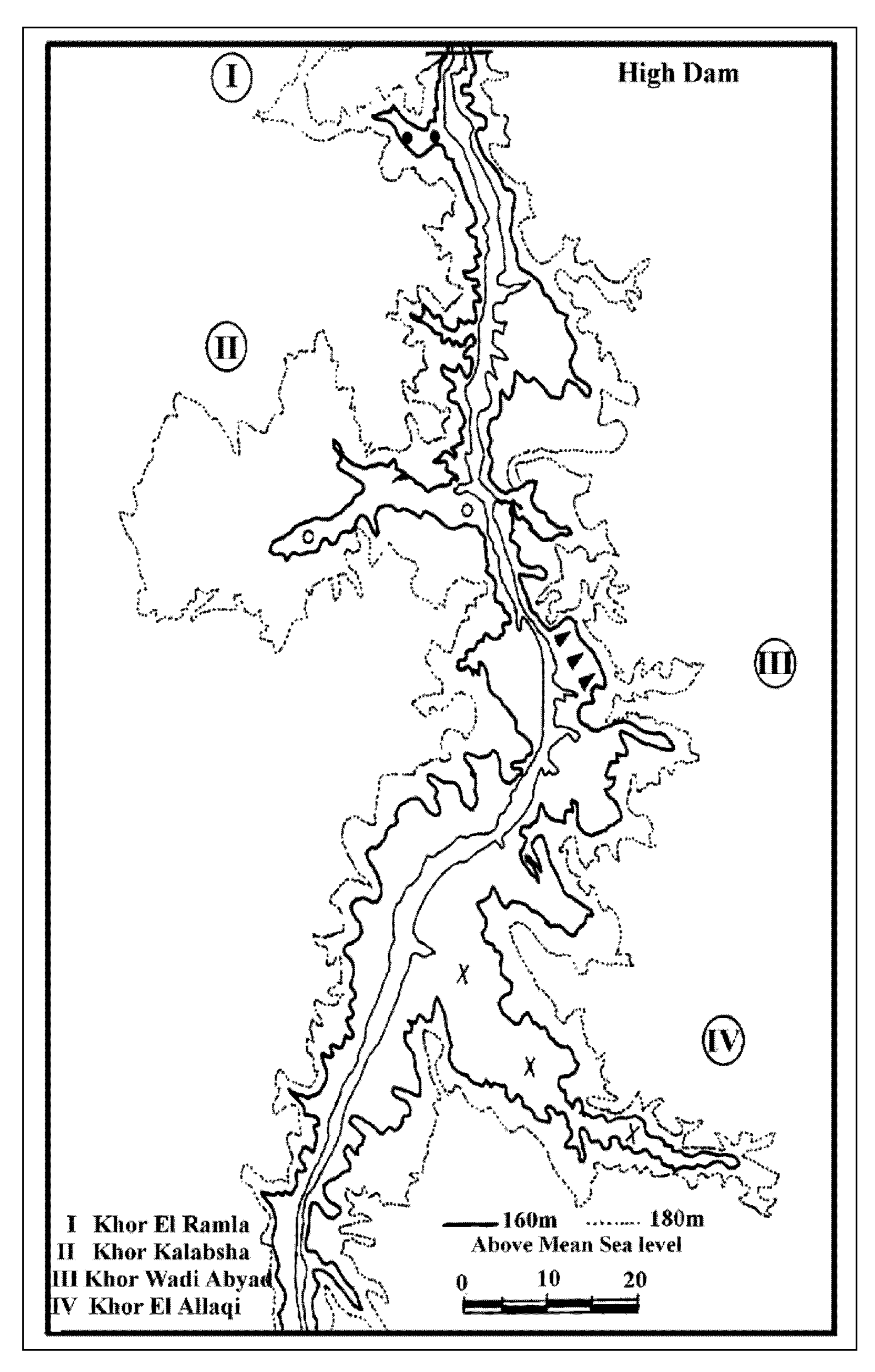


Fig. 59 **Location map showing water sampling sites (Gindy 1991).**

The seasonal variations of electrical conductivity in the eastern and western sides as well as in the main channel were studied by Fishar (1995). The latter author pointed out that the maximum conductivity was recorded in the eastern and western stations of Abu Simbel (232.3 and 262.8 µmhos cm^{-1}) and the main channel at El-Madiq (232.5 µmhos cm^{-1}). The maximum average values of electrical conductivity were recorded during summer being 240.5, 239.1 and 250.8 µmhos cm^{-1} in the eastern side, main channel and western side respectively. The lowest values were observed during winter and spring (Fig. 60, Fishar 1995).

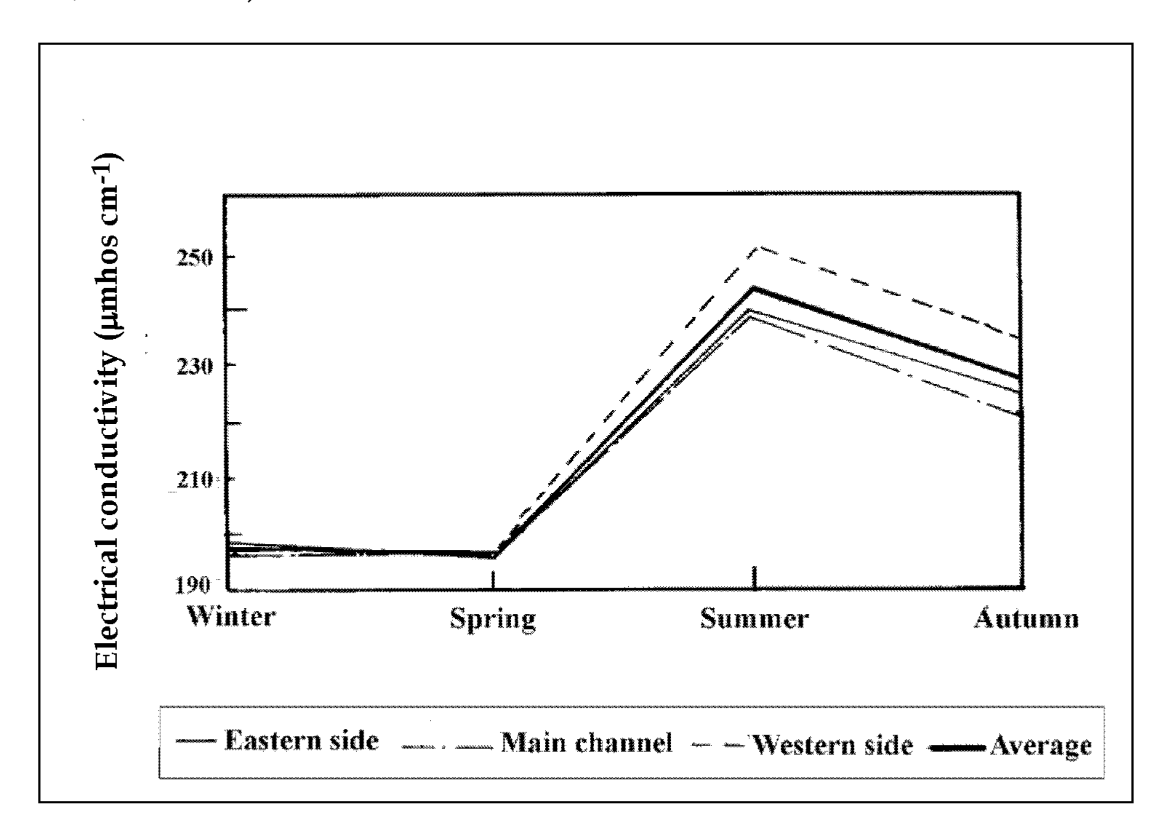


Fig. 60 **Seasonal variations of electrical conductivity (µmhos cm^{-1}) in Lake Nasser during 1993 (Fishar 1995)** [For localities refer to Fig. 15].

HYDROGEN ION CONCENTRATION (pH)

The pH values of the Lake water are on the alkaline side. Thus, in the main channel, the pH value varies between 7.8 and 9.6 in the surface waters, while it ranges between 6.8 and 8.6 in the bottom waters. Entz (1976) reported that in the surface layer, pH values up to 9.6 were recorded due to intensive assimilation processes. Elewa (1976) mentioned that in most localities pH values decreased with depth and the difference was greatest during July in many localities and in November in others. The same author postulated that, in spring khors showed higher pH values and wider range of difference with depth than in the main channel. In summer, however, the values of surface waters of open and khor waters were comparable to some extent.

Goma & Abdel-Rahman (1992a) pointed out that in 1983, the monthly variations of pH values at stations 2 (Kalabsha) and 3 (Allaqi) in the main channel of Lake Nasser showed a range between 7.9 and 8.9 (Table 36 and Figs. 61 and 62). The pH values seem to be uniform through the water column from 0 to 10 m depth. Comparatively low pH values (8.2-8.3) were recorded in November and December at both stations (Goma & Abdel-Rahman 1992a). This may be due to low density of phytoplankton and consequently low photosynthesis. This is correlated with high transparency during these two months (Fig. 62). Maximum pH values of 8.6-8.9 were recorded from May to July 1983 at the two stations. It seems that phytoplankton bloom and intensive photosynthesis during these months may be one of the causes of high pH values. This is correlated with low transparency during these months.

Table 36 **Monthly variations of pH values at two stations in the main channel (at 0 - 10m depth) of Lake Nasser during 1983.**

Month	Stn. 2 (Kalabsha)			Stn. 3 (Allaqi)		
	0.0	5.0	10.0	0.0	5.0	10.0 (m)
January	8.4	8.4	8.4	8.2	8.4	8.2
February	8.2	8.2	8.2	8.8	8.8	8.6
May	8.9	8.9	7.9	8.8	8.8	8.4
June	8.3	8.6	8.6	8.3	8.7	8.7
July	8.7	8.7	8.0	8.9	8.8	8.8
November	8.2	8.2	8.2	8.2	8.2	8.3
December	8.2	8.2	8.2	--	--	--

(Goma & Abdel-Rahman, 1992a).

In 1985, the vertical and seasonal variations of pH values at six stations on Lake Nasser indicates that they ranged between 6.9 and 9 (Abdel-Rahman & Goma 1992c - Fig. 64). The low range of pH fluctuation is supposed to imply that the Lake water has relatively high buffering capacity, which prevents abrupt changes of pH. The pH values were high from January to April 1985 at most stations, while they were low from September to October 1985. The decrease in pH coincided with the arrival of the flood water from the south. However, pH values were relatively low almost throughout the year at station 1 (Abdel-Rahman & Goma 1992c).

The above results indicate that pH values were above 8.5 measured mostly at the surface waters (Fig. 63), where photosynthesis seemed to be particularly active. Generally, the water of Lake Nasser is slightly alkaline. Therefore, it is favourable for biological processes in general and fish production in particular.

The seasonal, vertical and regional variations of pH values along the main channel of Lake Nasser during different years (1987 -1992) were studied

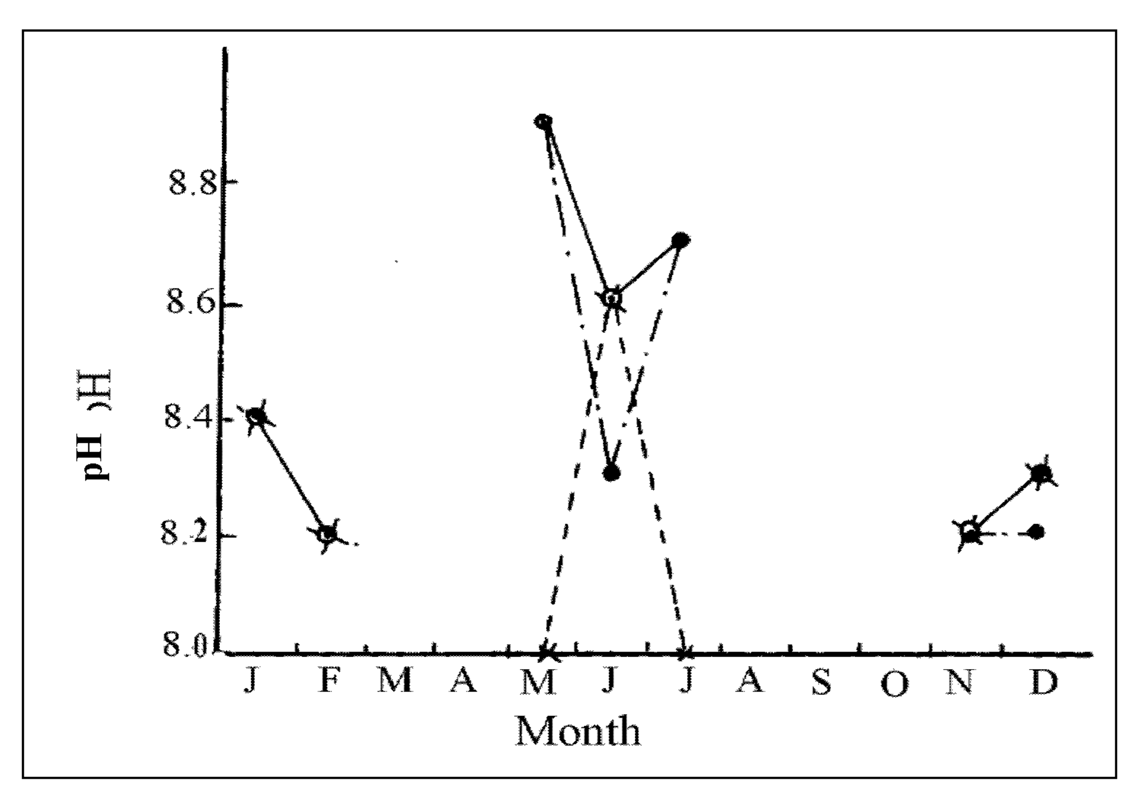


Fig. 61 **Monthly variations of pH values at Allaqi in 1983 (Goma & Abdel-Rahman 1992a)**

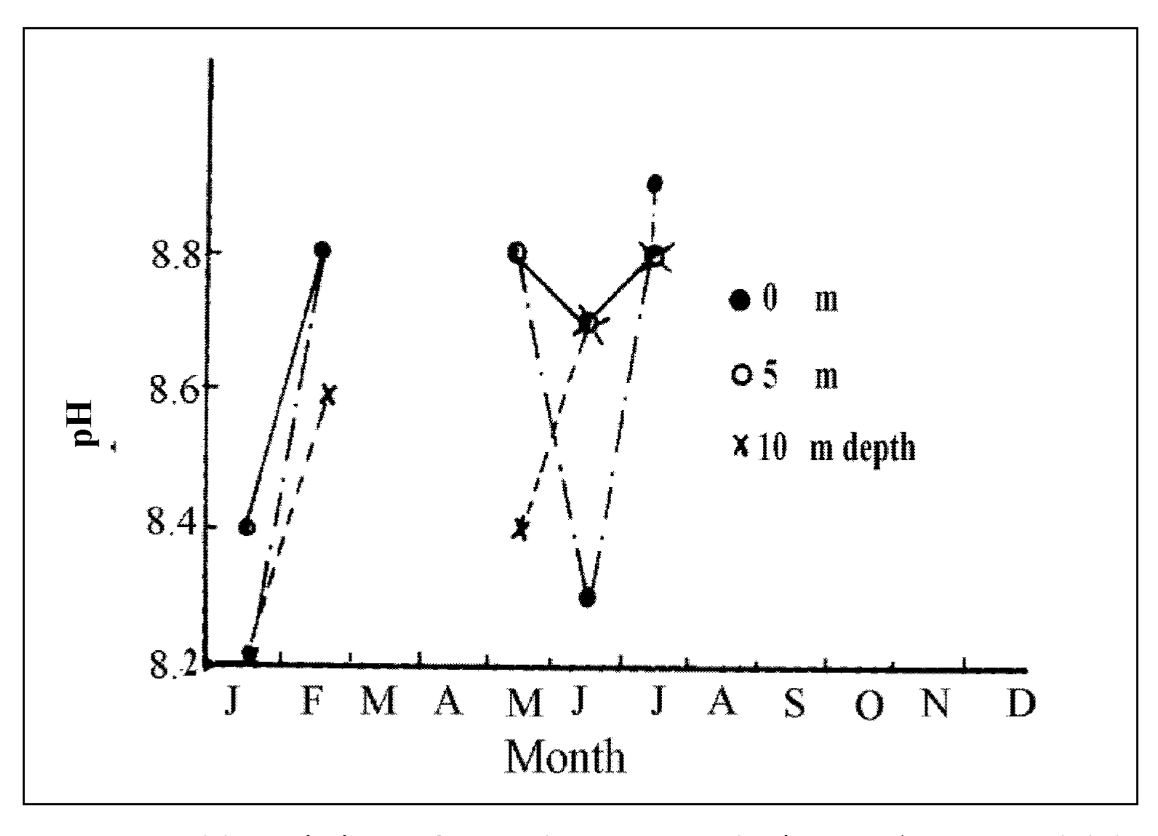


Fig. 62 **Monthly variations of pH values at Korosko in 1983 (Goma & Abdel-Rahman 1992a) [**For stations refer to Fig. 4**].**

by Abdel-Rahman & Goma (1995 a, b, c and d) and Abdel-Rahman (1995 a and b) and their results are summarized in Table 37. The highest values were recorded always at the surface and the lower in deep waters.

The seasonal variations of pH values in Lake Nasser during 1993 indicate high pH values in the two sides of the Lake in summer (8.47 and 8.35 for the eastern and western sides), while the highest pH value (8.05) was recorded during spring in the main channel. For the two sides and the main channel, the lowest pH values were recorded during winter (Fishar 1995 - Fig. 65).

Comparing the pH values of Lake Nasser with those of Volta Lake, it is found that, the mean pH values in the latter lake were much lower, mainly between 6.8 and 7.2, and sometimes less than 6. In this lake the pH never surpassed 8.1 in the open water. Free CO_2 was always present in Volta Lake at the surface, but especially in deep water where it sometimes surpassed 40-55 mg/1.

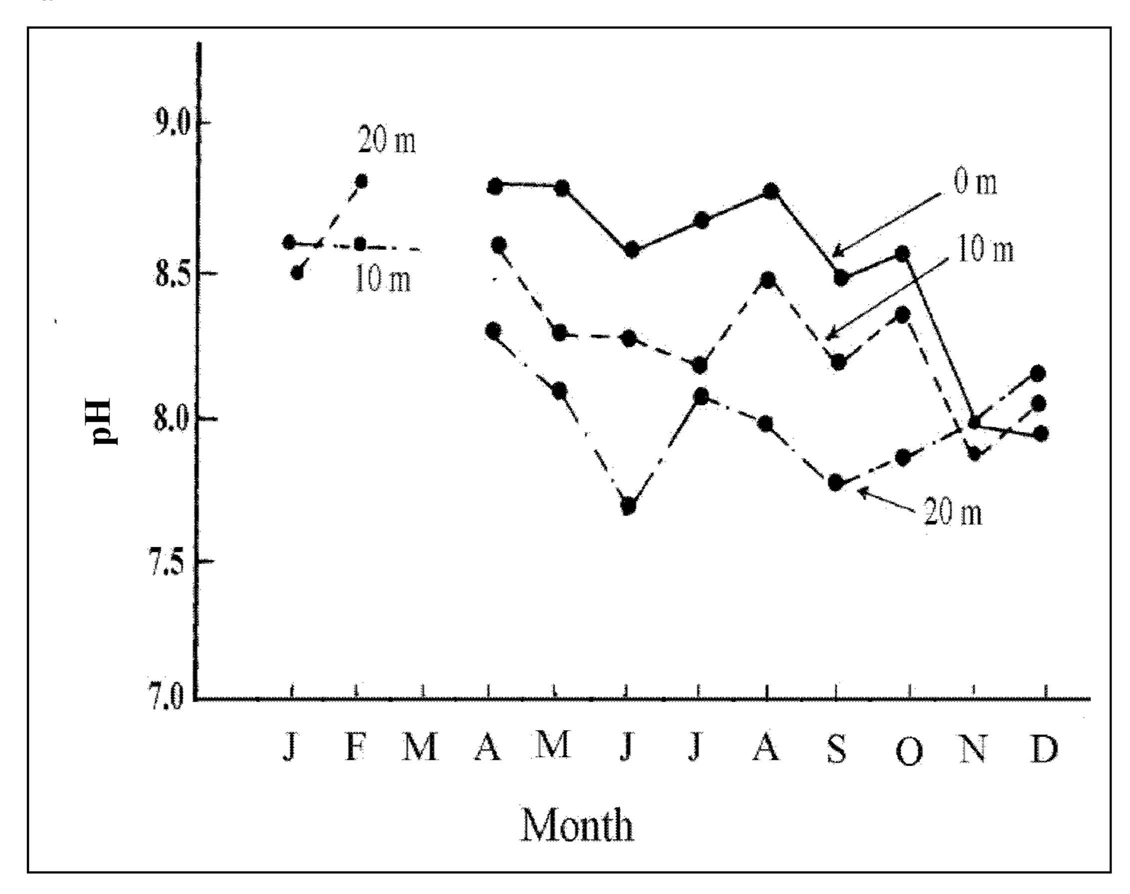


***Fig.* 63 Monthly variations of pH values at 0, 10 and 20 m depth in Lake Nasser in 1984 (Goma & Abdel-Rahman 1992b).**

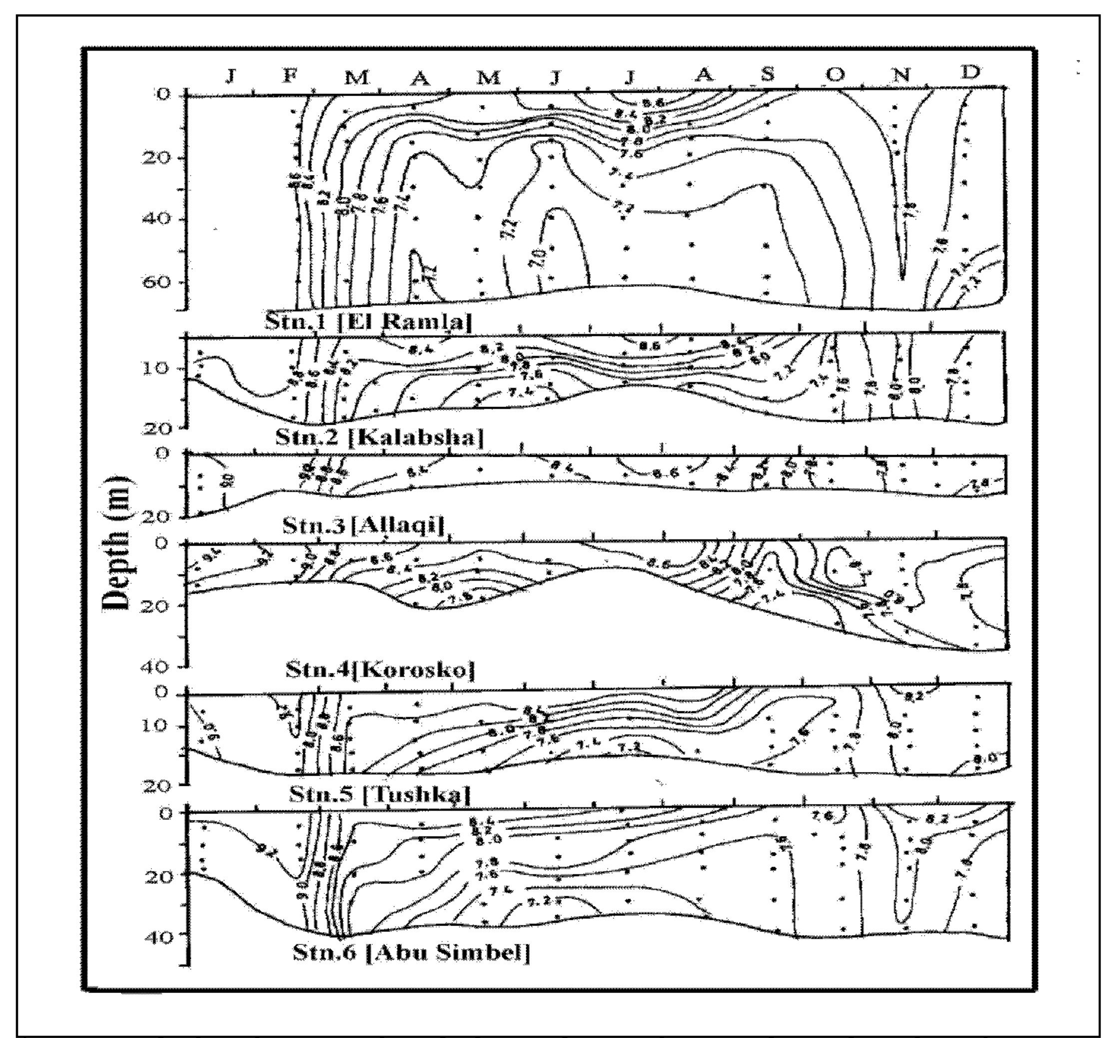


Fig. 64 **Vertical and seasonal variations of pH values at six stations in Lake Nasser in 1985 (Abdel-Rahman & Goma 1992c) [**For stations refer to Fig. 4**].**

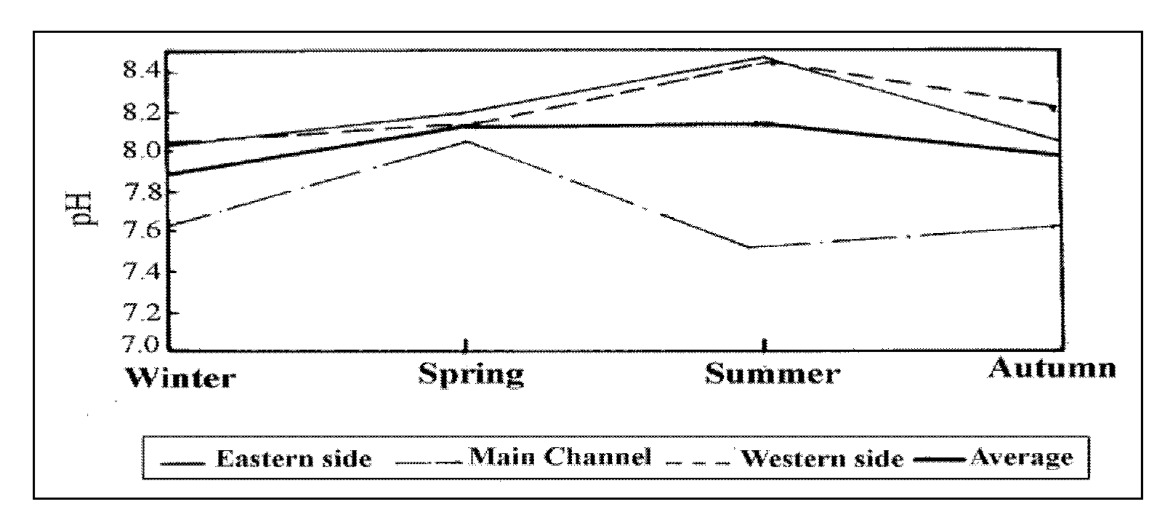


Fig. 65 **Seasonal variations of pH values in Lake Nasser during 1993 (Fishar 1995).**

Table 37 **Seasonal, vertical and regional variations of pH values along the main channel of Lake Nasser (1987-1992) [For stations refer to Fig. 4].**

	1987*	1988*	1989*	1990*	1991**	1992**
Range	6.8-8.9	7.44-9.18	7.14-9.09	7.17-8.94	7.47-8.92	7.07-8.92
High value	8.9	9.18	9.09	8.94	8.92	8.92
Stn.	6	4	6	4	6	4 & 6
Depth (m)	10	5	5	0	10	0
Month	(Dec.)	(June)	(April)	(July)	(Dec.)	(April)
Low value	6.8	7.44	7.14	7.17	7.47	7.07
Stn.	1	1	2	4	1	1
Depth	60	30	15	60	70	70
Month	(Oct.)	(Sept.)	(Sept.)	(July)	(Sept.)	(Aug.)
PH < 7						
Stn.	St. 1					
Depth	(bottom layers)	-------	-------	-------	-------	-------
Month	(June, Oct. & Nov.)					

* Abdel-Rahman & Goma (1995a, b, c and d). **Abdel-Rahman (1995a and b).

ALKALINITY

The alkalinity of Lake Nasser is mostly due to bicarbonate; the carbonate concentration is very limited. In the early years (1970) the **carbonate** concentration was 28 mg/l (Entz 1972). Elewa (1976) pointed out that the carbonate values decreased to about 17 mg/l for the surface waters, while bottom waters had lower or no CO_3^{2-} content. Aly (1992) showed that the carbonate concentration ranged from 0 to 32 mg/l with a mean of 15.5 mg/l. Abdel-Monem (1995) found that alkalinity as carbonate ranged from 0.0 - 28 mg/l, the maximum value was recorded at the bottom waters of Kalabsha. Higher values were usually encountered in the upper 3 m compared to 15 m depth and bottom (except in winter where the bottom layer had the highest concentration).

The **bicarbonate** concentration, however, is much higher and has shown a reverse pattern. For the main channel, the concentration had a range from 53.9 to 110.57 mg/l in 1970 (Nessim 1972) as compared to a range of 117 to 203.4 mg/l in 1974 - 1975 (Elewa 1976). For bottom waters the range was recorded as 110 to 174.5 mg/l in the latter period (Elewa 1976). Aly (1992) recorded lower bicarbonate concentrations ranging from 8 to 120 mg/l (mean of 76.5 mg/l). Abdel-Monem (1995) studied the bicarbonate concentration at 10 sites in the main channel at 3, 15m depth as well as at the bottom waters. He found that the bicarbonate concentrations fluctuated between 16.6 to 134.3 mg/l, the highest mean values at the three layers were recorded during autumn (98.2, 96.8 and 129.5 mg/l respectively) and the lowest values were

found during summer. It is obvious that the bicarbonate concentration of Lake

Nasser since 1970 uptill now remained almost constant with fluctuations within narrow limits.

Entz (1972) pointed out that the Lake is generally free from **CO_2**, while Elewa (1976) recorded low values (3.3 mg/l) in the deep waters at some localities of the lake.

In **Khor El Ramla**, the water **alkalinity** (CO_3) showed slight monthly fluctuations, being very low during summer (1.42 mg/l), slightly increasing in autumn (2.16 mg/l), attaining its highest value in winter (2.32 mg/l), then decreasing in spring (2.03 mg/l). No significant differences in alkalinity with water depth were observed (Abdel-Mageed 1992). Gindy (1991) found that the **carbonate** values ranged from 1.0 (bottom waters of Khor El Ramla) to 15.0 mg/l (surface waters of Khor El-Allaqi). The maximum average value of carbonate was encountered in the surface waters of Khor Al-Allaqi (13.0 mg/l), whereas the minimum was observed in the bottom waters of Khor El Ramla (1.5 mg/l). Generally, the carbonate values decrease from south (Khor El-Allaqi) to north (Khor El Ramla).

Gindy (1991) mentioned that the **bicarbonate** of **khor waters** fluctuated between 92 mg and 119 mg/l at the bottom and surface water of Khor El-Allaqi, whereas the relatively low values were recorded at the bottom waters of Khor Wadi Abyad (96 mg/l).

MAJOR IONS

Latif (1984a) reported that **chloride** concentration decreased mostly with depth. In the main channel, for the surface water, the chloride values recorded were 9.4, 18.0, 24.0 mg/l in 1974, 1976 and 1977 respectively (Latif & Elewa 1980). The lowest value so far recorded was 2.9 mg/l (Latif 1984a). Belal *et al.* (1992) pointed out that chloride concentrations were relatively high and varied between 7.29 to 19.22 mg/l with an average of 10.04 mg/l.

The **sulphate** concentration ranged form 5 to 15 mg/l and remained relatively constant during 1972 and from 1975 to 1977 (Latif 1984a). It seems that sulphate concentration remained nearly constant since the early filling of the Lake. Thus, Belal *et al.* (1992) showed that sulphate concentration in the Lake ranged from 1.0 to 15 mg/l. Shoreit *et al.* (1992) pointed out that sulphate concentration in the Lake decreased rapidly with depth and fluctuated between 12 mg/l at the surface and 3.0 mg/l at the bottom. Abdel-Monem (1995), however, recorded low sulphate values ranging from 0.90 to 9.86 mg/l with a minimum average of 1.63 mg/l near the bottom during summer. The low sulphate content of bottom layers may be attributed to low oxygen content leading to increase of sulphate-reducing bacterial activities i.e., sulphate to H_2S. Abdel-Monem (1995) found a positive correlation between SO_4^{2-} and chlorophyll *a* ($r \approx 0.78$), a finding which agrees with Beauchamp (1953), who

suggested that the growth of plankton in Lake Victoria and probably other African lakes, is restricted by the low sulphate content.

The concentrations of **Ca^{2+}** and **Mg^{2+}** were 25.26 and 10 - 11 mg/l respectively (Entz 1972). Latif & Elewa (1980) pointed out that during 1974 - 1976 the concentrations of the major cations, Na^{+}, K, Ca^{2+} and Mg^{2+} were 6.2-27.8, 1.9-8.0, 14.3-27.5 and 4.5-12.5 mg/l respectively. Thus, the basic ratio (Na+K): (Ca + Mg) is generally less than 1.0 in the Lake. Gindy (1991) mentioned that in the Lake waters the concentration of Ca^{++} ranged between 14.0 and 28.8 mg/l. The average distribution of Ca^{++} shows that the highest concentration of Ca^{++} (i.e. 26.3 mg/l) was recorded at the surface waters of Khor El-Allaqi as compared with the lowest value (i.e. 14.6 mg/l) in bottom waters of Khor Wadi-Abyad (Gindy 1991). The distribution of Ca^{++} in the middle waters denotes an increase from north to south, which is similar to the trend of $CO_3^{- -}$ content. This indicates that calcium occurs in the form of carbonates. A seasonal variation of calcium concentration in the lake water was observed, with a minimum of 12.8 mg/l in October and a maximum of 38.5 mg/l in February and the mean value was 21 mg/l (Belal *et al.* 1992).

Magnesium values fluctuated between 2.88 and 10 mg/l (Gindy, 1991) compared with 10-11 mg/l as recorded by Entz (1972). The lowest and highest values were recorded in the bottom waters of Khor El Ramla and middle waters of Khor Wadi Abyad respectively. The average distribution shows that the highest concentration of Mg^{++} (6.92 mg/l) was recorded in the middle waters of Khor Wadi Abyad, whereas the lowest concentration (3.34 mg/l) was recorded in the surface waters of Khor Wadi Abyad (Gindy 1991). Belal *et al.* (1992) showed that the magnesium concentration in the Lake water ranged from 5.8 to 19.5 mg/l.

Abdel-Monem (1995) found a positive correlation between Mg^{2+} and phytoplankton biomass as represented by chlorophyll *a* ($r \approx 73$). These results confirm the findings of Goldman (1960 and 1961) and Loffler (1964) who showed that Mg^{2+} is a major factor limiting photosynthesis in an Alaskan lake and Mount Kenya.

In khors **sodium** values varied between 11.1 mg/l (bottom waters of Khor El-Allaqi) and 15.1 mg/l (surface waters of Khor El-Ramla) (Gindy 1991). The average distribution of sodium shows that the highest concentration (13.8 mg/l) was recorded in the surface waters of Khor El-Ramla, whereas the lowest one (11.33 mg/l) was found in the bottom waters of Khor El-Allaqi (Gindy 1991). However, higher concentrations (6.2-27.8 mg/l) were previously recorded by Latif and Elewa (1980).

Much lower concentrations of sodium were recorded in 1993 (Abdel-Monem 1995) in the main channel of the Lake ranging from 3.15 mg/l at 3 m depth at Mariya in spring and a minimum of 0.89 mg/l at Adindan at 15 m

depth during autumn. There were no significant changes of sodium values at all stations during the four seasons (annual average 1.62 mg/l).

Potassium concentrations along the main channel ranged between 5.08 mg/l in summer and 2.13 mg/l at Adindan at 3 m depth. The average annual value was 4.03 mg/l at 3 m depth during summer and a minimum of 3.19 mg/l near the bottom in autumn (Abdel-Monem 1995).

NUTRIENTS

Among the four African man-made lakes (Volta, Nasser, Kainji and Kariba), Lake Nasser is the richest in nutritive salts. The concentrations of phosphate, nitrate nitrogen and silicon range between 0.02 to 0.52; 0.50 to 3.0 and 10 to 35 mg/l.

Nitrogen

a. Ammonium nitrogen (NH_4-N). Abdel-Monem (1995) found regional, seasonal and vertical variations of NH_4-N along the main channel of the Lake. The highest values were recorded near the bottom during autumn (range between 78.1 to 273.3 μg/l), while it was not detected in most localities at other depths in summer. The seasonal average fluctuated between a maximum of 178.4 μg/l near the bottom layer in autumn to a minimum of 6.8 μg/l at 3 m depth during the same season. The increasing NH_4-N level in the hypolimnion compared with the epilimnion in autumn may be attributed to liberation of NH_3 from the sediment/water interface (Harris 1986). Abdel-Monem (1995) explained the decrease in NH_4-N during summer as being due to nitrification processes that lead to oxidation of NH_4 to NO_2 and NO_3 as manifested by their average high values at the bottom layers which amounted to 22.6 μg/l for NO_2 and 111.9 μg/l for NO_3. In winter, nitrification is temperature limited so that the NH_4-N may build up in the Lake waters (Harris 1986).

b. Nitrite-nitrogen. Latif (1984a) pointed out that the nitrite nitrogen ranged between 5 and 180 μg/l. In his study of NO_2-N along the main channel Abdel-Monem (1995) recorded maximum values (66.7 μg/l) near the bottom in the vicinity of HD during summer which decreased to an undetectable value (0.0) in some stations in spring and autumn. The seasonal average values ranged from 28.4 μg/l near the bottom layer in winter and 1.3 μg/l near the bottom in autumn (annual average value = 10.7 μg/l).

c. Nitrate nitrogen (NO_3-N). Latif (1984a) found that the concentration of nitrate nitrogen in Lake Nasser range from 0.50 to 3.0 mg/l. In the **main channel**, high nitrate nitrogen concentrations were recorded in November, when it was 2-3 mg/l at the northern sector and 3.0 mg/l at El-Birba (Zaghloul 1985). Lower nitrate nitrogen concentrations were recorded in May, as they were 1.5, 0.6 and 0.4 mg/l at the northern sector, Adindan and Amada respectively. In August the lowest values were observed at the northern sector, while it was somewhat high in the southern sector and this is attributed to the

effect of incoming flood (Zaghloul 1985). During the same month Latif (1984a) recorded the range of nitrate nitrogen concentration as 0-0.8 mg/l in the southern part of Lake Nubia and a range of 0.6-1.0 mg/l in the northern part at Wadi Halfa and Sarra.

Elewa & Azazy (1986) pointed out that the nitrate-nitrogen fluctuated between 64 - 72 µg/l and 290 to 0.0 µg/l during 1974 and 1984. The zero value recorded in spring 1984 may be correlated with the high rate of photosynthesis by phytoplankton. This high activity of phytoplankton was correlated with nutrients, as measured by increase in electrical conductivity during summer and winter (Elewa & Azazy 1986). Ahmad *et al* (1989) recorded maximum levels of NO_3-N in June 1983 amounting to 301.2 µg/l at 15 - 20 m depth. In 1993 Abdel-Monem (1995) recorded high concentrations in winter and spring with a maximum value of 768.5 µg/l near the bottom at Abu Simbel in winter. Lower values were recorded in summer and autumn with a minimum of 3.9 µg/l at 3 m depth near the HD and Abu Simbel in summer. The obvious decline in NO_3-N in some locations can be principally attributed to its utilization by phytoplankton (Hutchinson 1957) or to the reduction by denitrifying bacteria (Munawar 1970 and Seenayya 1971). Shoreit *et al.* (1992) showed that at the surface no nitrate could be measured but increased considerably with increasing depth and reached a maximum of 1750 µg/l at the bottom.

In **khors**, higher nitrate concentrations were recorded in November than those in May and August (Zaghloul 1985) and generally nitrate concentrations in khors maintained similar values recorded for the main channel. Latif (1984a), however, presented higher values of nitrate concentrations in the main channel than those in the khors. Elewa (1985) recorded a maximum nitrate concentration (406.8 µg/l) in the bottom waters of Khor Tushka and a minimum value (113 µg/l) in the bottom waters of Khor Kalabsha in August 1981 (Table 38). The highest NO_3-N was recorded in May/June 1982, April, June, July 1983 parallel with the minimum value of algal count (Belal *et al.* 1992 - Table 45, Fig. 71).

d. Total organic nitrogen (TON). It was estimated by Abdel-Monem (1995) along the main channel who recorded seasonal, vertical and regional variations. The highest total organic nitrogen concentrations were found in winter at all depths ranging from 14.45 - 9.44 mg/l (average 11.61 mg/l). Minimum values were observed in summer ranging from 5.36 - 0.80 mg/l. Seasonal average values fluctuated between 12.09 to 1.8 mg/l. The high level of organic nitrogen in the Lake may be attributed to the high population densities of phytoplankton. McCarthy (1980) attributed the high content of organic nitrogen in freshwater bodies to the direct fixation of N_2 gas by the nitrogen fixing prokaryotes (bacteria and /or blue-green algae), thus contributing more than 2 - 3 times the nitrogen flux from other resources at a certain period (Horne & Fogg 1970).

Table 38 **Nutrient concentrations in some khors of Lake Nasser during 1982 - 1983 (Elewa 1985a).**

Khor	August, 1982		November 1982		May, 1983		September, 1983	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
				PO_4- P µg/l				
El-Birba	48.9	48.9	48.9	65.2	32.6	48.9	45.64	55.42
Manam	45.46	48.9	58.68	163	29.34	29.34	52.16	48.9
Kalabsha	29.34	65.2	52.16	48.9	32.6	65.2	29.34	78.24
Tushka	32.6	32.6	58.68	61.94	45.64	48.9	58.68	58.68
				NO_3-N µg/l				
El-Birba	203.4	158.2	339	271.2	180.8	316.4	203.4	180.8
Manam	180.8	180.9	180.8	361.6	203.4	271.2	180.8	180.8
Kalabsha	180.8	113	203.4	226	113.0	180.8	226	271.2
Tushka	203.4	226	384.2	406.8	180.8	180.8	180.8	203.4
				SiO_2 mg/l				
El-Birba	25	21.3	20.0	14.5	16.3	13	15	18
Manam	12.5	18.8	12.5	20	11.3	8	16.3	15
Kalabsha	30	18.8	20	20	15	12.5	22.5	22.5
Tushka	17.5	17.5	12.5	15	20	20	18	20

Phosphate

In the early years of Lake Nasser filling high concentrations of dissolved phosphate were recorded ranging from 0.02-2.0 mg/l (Entz 1972). In 1976/1977 Latif & Elewa (1977) recorded much lower concentrations ranging from 0.055 to 0.52 mg/l being higher in the bottom than surface water layers. In 1981 Zaghloul (1985) found that the dissolved phosphate in the surface waters in the **main channel**, ranged between 0.07 and 0.52 mg/l, with the lowest value at El-Birba and Amada in winter and the highest one at Adindan in autumn. Such high values appear as due to the effect of flood water. A reverse relation appears to exist between the concentration of dissolved phosphate and water transparency, as for example the high phosphate content (0.52 mg/l) recorded at Adindan in autumn corresponding to a low water transparency with Secchi depth of 65 cm. On the other hand, low concentration of dissolved phosphate at El-Birba in winter (0.07 mg/l) corresponded to high water transparency of 220 cm. (Zaghloul 1985). The latter author pointed out that at 10 m depth, the dissolved phosphate concentration varied between 0.06-0.50 mg/l for the main channel with the minimum value in spring and maximum one in autumn. Its distribution in winter was high at El-Birba (0.2 mg/l) but decreasing to 0.09-0.12 mg/l in the other localities of the main channel (Zaghloul 1985). In summer, the dissolved phosphate concentration decreased southwards from 0.5 mg/l at El-Birba to 0.1 mg/l at Adindan (Zaghloul 1985). Belal *et al.* (1992) recorded a mean value of 0.15 mg/l in surface waters of the Lake.

Abdel-Monem (1995) found that phosphate concentrations in the main channel ranged from 0.193 mg/l near the bottom during autumn at Tushka to nil at various depths and localities in summer and spring. The highest annual average

(0.136 mg/l) was recorded in spring at 3 m depth while the lowest (0.0042 mg/l) in summer at 3 m depth. It seems that during the last two decades the dissolved phosphate concentration remained, more or less, constant.

In the early years of storage in Lake Nasser, Nessim (1972) found that dissolved phosphate concentration in **khor** waters was 0.55 mg/1 with maximum values in Khor El-Birba. Zaghloul (1985) mentioned that dissolved phosphate concentration in the surface water of khors ranged between 0.07 and 0.25 mg/1 with the lowest value at Khor Kalabsha in March and the highest at Khor Wadi Abyad in August. At 10 m depth the phosphate concentration varied between 0.06 and 0.60 mg/1 in khors, with minimum values in spring and maximum in autumn, while in winter it was 0.14 mg/1 (Zaghloul 1985). In Lake Nasser the maximum value of phosphate phosphorus (0.163 mg/l= 0.52 mg/1 dissolved phosphate) was recorded in the bottom water at Khor Manam in November, and the minimum value (0.0293 mg/l= 0.093 mg/1 dissolved phosphate) in the surface water of Khor Kalabsha in August (Elewa 1985b - Table 38). The latter author pointed out that the highest level may be influenced by the biological activity and distribution of cations in the sediments, phyisco-chemical conditions such as pH, redox potential and mineral composition of the sediments. Elewa's findings were in accordance with those of Golterman (1975) who showed that in summer the algal growth may reduce the phosphate. Hutchinson (1957) pointed out that in productive lakes, with clinograde oxygen curves, there is an increase in soluble phosphate in the oxygen-deficient part of the hypolimnion due to decomposition of sinking plankton, but in most cases it is primary caused by liberation of phosphate from sediments.

Adsorption of PO_4^{-3} on colloidal $Fe(OH)_3$, fine particles of $CaCO_3$ and on clay minerals, which occur in most Lake sediments originates from eroded material transported into the Lake by the river (Elewa 1985b). He adds that PO_4^{-3} anions are taken up from water by alumina or by clay minerals through chemical bonding of the anion to positively charged edges of the clays on which substitution of PO_4^{-3} or silicate in clay structure. Adsorption is favoured by lower pH and also by freshly precipitated ferric and aluminum hydroxides (Olphen 1963).

Thomas (1968) showed that the phosphate uptake from the Lake water depends on the presence of phytoplankton and by organic compounds and ferric complexes in the mud, at the same time, phosphate is released into solution from the superficial layer of the mud when a lake is stratified in the anaerobic deep water. The phosphate concentration in the water overlying sediments has a buffering action by solubility and adsorption or ion exchange equilibrium at the sediment-water interface (Stumm & Morgan 1970 and Golterman 1973).

Silicates

In the **main channel** of Lake Nasser, the silica concentration ranged from 10 to 35 mg/1 in 1976-1977, with higher concentrations in August and minimum levels in May. These, values are higher than those recorded for 1975-1976, when the range

was 8.1-15.5 mg/l (Latif & Elewa 1980). Zaghloul (1985) observed a reverse relation between the concentration of silicate and blooming of diatoms particularly at the southern sector of Lake Nasser, where *Melosira granulata* reached the maximum predominance of 9-17 million cells/l.

Talling (1976a) mentioned that low concentration of silica (2-2.8 mg/l) occurred in the head water lakes, in comparison with 10-24 mg SiO_2/l in the river stretches of Sudan and Egypt. This mainly results from depletion by planktonic diatoms and partially from the dissolution and its transfer of ubiquitous rock and soil silicates in running waters.

Khor waters may contain more silicates than the main channel (Latif & Elewa 1980). In khor waters of Lake Nasser, the silicate concentration (Table 38) varied between 8 mg/l in the bottom water of Khor Manam in May and 30 mg/l in the surface water of Khor Kalabsha in August (Elewa 1985b).

According to Golterman (1975), silicon oxide is of great significance as a major nutrient for diatoms of most lakes. Thus, silica comes to the reservoir from predominantly recycling processes, (diatom decomposition) and river loading. Again, silica usually increases in the deep water of lakes during summer stratification in the anaerobic deep water, having clinograde oxygen curves, which have an important mechanism, by which silica is removed from lake water. Zaghloul (1985), however, observed no particular trend in the concentration of silicate with depth.

CONCLUSIONS

The **oxygen concentration** of Lake Nasser varies seasonally, vertically and horizontally. In winter, the whole water mass is well oxygenated and almost homogeneous. However, there is a slight variation of dissolved oxygen among the different depths. Generally, high oxygen concentrations are recorded at all stations of Lake Nasser in spring of different years. The rapid increase of oxygen concentrations of surface waters (values of 150 % or even 200 % saturation) is mainly due to photosynthesis of rich phytoplankton populations. In summer, high or moderate oxygen concentrations are recorded in surface water layers. With increase of depth, a sharp decrease in oxygen concentration is observed and reaches 0 ml/l at bottom water layers. It is worth mentioning that the thermal stratification coincides with the formation of an oxygenated epilimnion and oxygen-free hypolimnion.

The oxygenated epilimnion becomes deeper southwards, i.e. the depth of oxygenated layer ranges from 8 to 10 m in the northern part of the Lake as compared with about 20 m at Adindan, the southernmost area. In autumn, the drop in temperature is accompanied by the initiation of destruction of thermal and oxygen stratification with the incoming flood in the southern part of Lake Nubia and progresses northwards. The epilimnion becomes thicker than in the remaining northern part of the reservoir. The difference in temperature and oxygen content with depth becomes narrower up to the Second Cataract than in the remaining

northern part of the Lake. Moderate and sometimes high concentrations of oxygen are recorded in autumn in the surface water layers. But, a slow decrease of oxygen concentration is observed with the increase of depth and sometimes reaches 0 ml/1 in the bottom layers.

It seems that the average oxygen concentration during all seasons, i.e. winter, spring, summer and autumn is higher in the western side of Lake Nasser than in the eastern. Meanwhile, at both sides of the Lake, the average oxygen concentration is higher than in the main channel. In Khor El Ramla the surface waters (0-5 m) are well oxygenated throughout the year. From January to April the whole water column is well oxygenated. In May the oxygen content shows a decrease below 10 m depth. In summer, thermal stratification is well pronounced with an upper oxygenated epilimnion, a poorly oxygenated metalimnion (5-20 m) and a completely oxygen depleted deep layers.

Electrical conductivity in Lake Nasser exhibits seasonal, vertical, horizontal and local variations ranging from 186 to 299 μmhos cm^{-1} for surface waters of the main channel. Conductivity of deep waters (50 m depth) show lower values than those of surface waters in winter and autumn and the difference is usually greater in autumn. For surface waters, the electrical conductivity values ranged in 1979 from 190 to 245, 210 to 252, 210 to 228 and 199 to 245 μmhos cm^{-1} in winter, spring, summer and autumn respectively, compared with 190 - 218 (average 198.8), 186 - 222 (average 204.5), 219 - 242 (average 238.3) and 215 - 260 (average 229.7) in 1993/1994 in winter, spring, summer and autumn respectively. The electrical conductivity values of Lake Nasser since its early filling remained, more or less, constant affected yearly by the flood water. In winter and spring, the conductivity values decrease southwards; while in summer the values show a gradual decrease from the HD to Amada, but increases at Tushka. In autumn the electrical conductivity decreases from the HD to Kalabsha, then increases southwards to El-Madiq, followed by a gradual decrease to Tushka and greater decrease to Adindan. Variation of electrical conductivity follows water movements of the floods. Highest concentrations are recorded in front of flood waters. Lower conductivity during the flood is due to low conductivity of flooded water from Blue Nile, which contributes about 84 % of Nile water.

In khors, the electrical conductivity is low in bottom waters (155 μmhos cm^{-1} at Khor Kalabsha) and high in surface waters (290 μmhos cm^{-1} at Khor El Ramla). Generally, in surface water of khors, a marked increase in the values of electrical conductivity is observed from south to north. The inflow of flood from the south lowers the electrical conductivity at Khor Tushka due to the precipitation of the suspended matter leaving the water nearly free of electrical minerals containing ionic salt.

Generally, the **pH values** of Lake Nasser lie on the alkaline side. Thus, in the main channel, the pH value varies between 7.8 and 9.6 in the surface waters; while it ranges between 6.8 and 8.6 in the bottom waters. In most localities, pH values decrease with depth. In spring, khors show higher pH values and wider range of

difference with depth than in the main channel. However, in summer the values of surface waters of open and khor waters are comparable to some extent.

The **alkalinity** of the Lake is mostly due to bicarbonate, while the carbonate concentration is very limited. The **carbonate** values of surface water of the main channel ranged from 0 - 32 mg/1 with a mean of 15.5 mg/1. In Khors it ranged from 4 mg/1 (bottom waters of Khor El Ramla) to 13 mg/1 (surface water of Khor El Allaqi). Generally, the carbonate values decrease form south (Khor El-Allaqi) to north (Khor El Ramla).

It seems that a decrease in **bicarbonate** concentration occurred in recent years. Thus, while Elewa (1976) recorded a range of 117-203.4 mg/1 in 1974 - 1975, Ali (1992) recorded lower bicarbonate concentrations (8 - 120 mg/l). In the early years of Lake Nasser filling studies showed that it is generally free of CO_2 (Entz 1972), but later low values of CO_2 (3.3 mg/l) was recorded in deep waters in some localities (Elewa 1976).

The concentration of **major cations** i.e. Na^+, K, Ca^{++} and Mg^{++} range between 6.2 - 27.8, 1.9 - 8.0, 14.3 - 27.5 and 4.5 -12.5 mg/1 respectively. Chloride concentrations were relatively high and varied between 7.29 and 19.22 mg/1 with an average of 10.04 mg/1. It seems that sulphate concentration is nearly constant (0.90 - 15 mg/l) since the early filling of the Lake.

The **dissolved phosphate** concentration in surface water range between 0.02 and 0.52 mg/1 being generally higher in the bottom than surface water layers. Lowest concentrations were recorded in February associated with the highest algal counts in winter (Table 45), while the highest values were in November. In summer phosphate concentrations decreased southwards where the highest phytoplankton standing crop was recorded. It seems that khors are richer in phosphate than the main channel. During the last two decades the phosphate concentration in Lake Nasser remained, more or less, constant.

The concentrations of NH_4-N, NO_2-N, NO_3-N and total organic nitrogen range from 0.078 to 0.237; 0.05 to 0.180; 0.0 to 3.0 and 1.8 to 14.45 mg/1. The decrease of NO_3-N in summer may be attributed to its utilization by phytoplankton or to the reduction by denitrifying bacteria. Increase of NO_2-N and NO_3-N may be due to the nitrification processes that lead to oxidation of NH_3 to NO_2 and NO_3 as manifested by average high values at the bottom layers. High NO_3-N values recorded in August in the southern region may be due to the effect of incoming water rich in nitrates.

Silicon concentrations range between 10 to 35 mg/1, khors being richer in silicon than in the main channel. A reverse relationship was observed between silicon concentrations and diatom blooms especially in the southern region of the Lake.

Chapter 5
Flora

AQUATIC MACROPHYTES

Major changes have occurred in the flora of the Nile system in Egyptian Nubia in recent years, following the completion of the Aswan High Dam in 1964. In 1963, the area of the Nile Valley which was to become Lake Nasser had a relatively rich submerged and emergent flora (57 species, of which 6 were euhydrophytes) before the construction of the Aswan High Dam (AHD) (Boulos 1966). After the construction of AHD, Springuel & Murphy (1991) during 1980-1986 recorded 9 species of euhydrophytes, while Ali (1987) recorded 7 species only. Changes in aquatic vegetation may be due to changes in the water level regime and/or changes in the physico-chemical factors following waterbody regulation (Ali *et al.* 1995). The latter author discussed the effect of physico-chemical factors of both water and hydrosoil on the distribution of macrophyte vegetation in the River Nile in Upper Egypt (Lake Nasser, Aswan Reservoir and the Nile).

Erosion of the littoral zone is a natural phenomenon occurring in regulated bodies and is often linked closely with wave action (Smith *et al.* 1982). Ali *et al.* (1995) show that the littoral zone of Lake Nasser is characterised by a coarse hydrosoil texture, which may be formed due to the water level fluctuation and exposure to waves. As a result of the construction of the AHD, the new littoral zone of Lake Nasser has mainly a sandy substrate, as the submerged area was previously a desert. Most of the silt which had been brought by the floods, was accumulated behind the dam. Such accumulation of silt, in the north section of the Lake, gave a hydrosoil texture of clay loam. This texture is reflected in the species composition, being similar to that of the southern section of Aswan Dam. Thus, abundant growth of *Najas horrida* was recorded in both zones. Some of the silt was deposited on the shores and khors on both sides of the Lake. Due to the water level fluctuation and wave action, the

accumulated silt is washed from the banks and accumulated in the main channel, leaving behind sandy or sandy loamy sand banks where *Potamogeton lucens* (= *P. schweinfurthii*) and *Najas marina* subsp. *armata* are the dominant plants.

It seems that the abundance of a species differs with different water level fluctuation regimes. An extended range of water level fluctuation results in the mortality of aquatic vegetation caused by the absence of low light conditions (Rorslett 1989). Therefore, extreme changes in water levels give rise to communities that are extremely species poor or absent and so the littoral zone is impoverished (Smith *et al.* 1982).

Springuel & Murphy (1991) pointed out that habitat disturbance appears to be an important pressure acting upon the macrophyte population in Lake Nasser. The littoral zone is prone to massive disturbance, caused by water level fluctuations. Marginal beds of macrophytes may be exposed to the air (and to extreme heat and aridity), or submerged deep in the water column, at irregular intervals during the year, with potenially catastrophic impact on established plant populations. Murphy *et al.* (1990) showed that all macrophyte species ocurring in Lake Nasser show a strong element of disturbance-tolerance traits in their strategy type.

The highest amplitude of water level fluctuation in Lake Nasser was recorded in 1988, during the drought period. The mean monthly level of the Lake dropped to as low as 150.62 m above mean sea level on 20th and 21st July, 1988, about 30.68 m lower than the maximum level of the Lake in 1998 (181.30 m MSL). First, continuous low water level exposed the littoral shallow water habitats, and submerged macrophytes became exposed and desiccated. Following this, a period of continuous high water level caused low-light conditions for the same area of the littoral zone. The occurrence of these two events in a short period caused substantial mortality of the submerged aquatic plant communities during the drought period in 1988 (Ali *et al.* 1995). The initial community has *Najas horrida* A.Br.ex Magn. as the dominant species, with six other species present (Ali 1987). Following the destruction of that community, *Najas marina* L. subsp. *armata* (Lindb.) Horn became dominant, with four other taxa present (*Najas horrida, Zannichellia palustris* L., *Vallisneria spiralis* L. and *Potamogeton schweinfurthii* A. Benn.) (Ali *et al.* 1995).

Euhydrophyte species

The following represents the submerged hydrophytes (euhydrophytes - flowering and non-flowering) recorded in Lake Nasser.

1- *Najas marina* subsp. *armata* (Lindb.). Until recently this plant was restricted in Egypt, to the Nile Delta, Fayoum, the Mediterranean coastal strip, Isthmic region, and Oases of the Western Desert (CAI*, Täckholm 1974). In 1973, it was

* CAI=Cairo University Herberium

recorded in Lake Nasser by El-Hadidi (1976), and Entz (1976). This species has subsequently spread vigorously in Lake Nasser and, to a lesser extent, other waters in Egyptian Nubia (Triest 1988). *Najas marina* subsp. *armata* is currently a dominant species in Lake Nasser, showing vigorous growth throughout the Lake littoral region during 1980-86 (Belal *et al.*1992). In 1988-89, it made up about 40% of the total standing crop. *Najas marina* occurs mainly in Lake Nasser, characterized by alkaline water and high electrolyte concentration. It grows on sand, clay, silt, clay with shells and thick organic matter. In most cases *Najas marina* is observed on an organic substrate covered with a layer of sand or clay. Though the tendency to form extensive pure stands, inhibiting colonization by potential competitors is characteristic of *Najas,* most species are of local occurrence (Ali *et al.* 1995). However, with respect to their vigorous growth and individual seed production, the biotic importance of *Najas* as a source of food for many sorts of waterfowl should not be underestimated.

2- *Najas horrida* A. Br. This species was confined to Lower Egypt and the oases prior to the filling of Lake Nasser, although specimens in CAI* are confused with *Najas pectinata* (Parl.) (Täckholm 1974, Triest 1988). It has now become abundant in the shallow waters of numerous khors (inundated wadis and side-arms) of Lake Nasser, often codominant with *Najas marina* subsp. *armata* (Belal *et al.* 1992). *Najas horrida* shows considerable morphological plasticity in its general habitat which may be robust, with curved rigid leaves or slender with straight lax leaves. Concerning the plasticity of *Najas horrida,* there could be a relationship between very compact specimens and the total mineralization of the water.

3-*Vallisneria spiralis* L. This species was recorded from the Aswan High Dam (Abdallah *et al.* 1972). It was also reported in 1968 by El-Hadidi & Ghabbour (1968) from three separate locations around Aswan. It remains common in all Nubian waters, including both major impoundments, and the river north of the two Dams (Belal *et al*. 1992). Ali (1987) pointed out that this rooting hydrophyte grows in shallow waters of many khors in both sides of Lake Nasser.

4- *Zannichellia palustris* L. This species is widespread in Egypt, occurring in the Nile Valley, Mediterranean, Isthmic and Oases regions (CAI and Täckholm 1974). In Egyptian Nubia it was recorded by El-Hadidi & Ghabbour (1968) in the Aswan Dam Area (CAI) and by Täckholm (1974) from irrigation canals near Allaqi village (CAI). Other records confirm that the species was present pre-1964 in water courses in the Upper Nile Valley, subsequently inundated by Lake Nasser (Abdallah *et al.* 1972, Boulos 1966, El-Hadidi 1976, El-Hadidi & Ghabbour 1968). It remains quite widespread in Egyptian Nubia, including Lake Nasser, but does not form dense stands (Springuel 1981, 1985 a and b).

This tiny submerged hydrophyte was recorded in very shallow khors in the southern region of the Lake (Ali 1987).

5- *Potamogeton lucens* L. (= *P. schweinfurthii* A. Benn.). This species was found to be very rare in the Nile Delta, eastern Mediterranean coastal region, and Isthmic regions (Täckholm 1974). Small stands of this species were recorded by Springuel as *Potamogeton nodosus* in 1980 in Lake Nasser near Khor Kalabsha, in the northern sector of the Lake. Later, Ali (1992) proved it was an abundant growth of *P. lucens* in the same area.

6- *Potamogeton crispus* L. Records in CAI and Täckholm (1974) suggest that this species has long been widespread in Egypt: common in the lower Nile, Sinai, the Isthmic Desert, Mediterranean region, and Oases. The plant was recorded from the Nile at Edfu, Kom Ombo, Aswan, and the Aswan Reservoir (CAI). Its presence in the Nile in Egyptian Nubia prior to construction of the Aswan High Dam was reported by many authors (Abdallah *et al.* 1972, Ahti *et al.* 1973, Boulos 1966 and El-Hadidi & Ghabbour 1968). The plant remains were common in the Nile downstream of the Aswan Dam. It was not recorded during the early years of the formation of Lake Nasser (Entz 1976), but was slowly invading the impoundment, being first recorded by Imam (CAI). Beds of *P. crispus* were confirmed as present in the northern sector of the Lake in 1979 by Springuel. Ali (1987) pointed out that this submerged hydrophyte was rare in the southern region of the Lake, confined to khors with shallow water and slow current. In later surveys this species was not recorded, and it may have been lost from the Lake (Belal *et al.* 1992).

7- *Potamogeton pectinatus* L. A widespread aquatic weed of irrigation and drainage canals in the Nile Delta. *P. pectinatus* also occurs in the River Nile valley, Oases, Mediterranean and Isthmic Desert regions of Egypt (CAI, Täckholm 1974). The presence of the plant in Egyptian Nubia before the construction of the Aswan High Dam is confirmed by several reports (Abdallah *et al.* 1972, Ahti *et al.* 1973, Boulos 1966, El-Hadidi 1976 and El-Hadidi & Ghabbour 1968). Entz (1976, 1980b) pointed out that the spread of macrophytes on a large scale in Lake Nasser started in 1972-73, with the development of stands of *P. pectinatus* in shallow sandy areas of the Lake. *P. pectinatus* was more common in the southern than in the northern sectors of Lake Nasser. *Potamogeton pectinatus* shows phenotypic changes in growth, so that photosynthetic tissue production is maximized near the water surface under varying water levels. This plant was not observed in the Lake during recent years (Belal *et al.* 1992).

8- *Potamogeton trichoides* Cham. & Schlecht. The first record of this species in Egypt was in May 1962 by Täckholm and El-Hadidi, from irrigation channels near Aswan. The plant was recorded in Lake Nasser in 1978 by

Imam in Khors Tushka and El-Malki (CAI). During 1981-82 it was abundant in the northern sector of the Lake (Springuel 1985b). Between 1982-87, the major fall in water coincided with the disappearance of *P. trichoides* from the northern sector, although it remained as a rare species in the southern sector of the Lake, near the Sudanese border. However, recent surveys showed that *P. trichoides* could have disappeared from the Lake (Belal *et al*. 1992).

9- *Potamogeton perfoliatus* L. It is found in canals in the Nile near its banks. It was discovered for the first time in Egypt by Täckholm in 1951 growing in the recently constructed freshwater reservoir 'Sadd el Rauwafaa' in northern Sinai. Before inundation by Lake Nasser, it was discovered in the Nile at Abu Simbel and Ballana (Boulos 1966).

10- *Nitella hyalina* (DC) Agardh. This macroalga grows in Lake Nasser, not to any great depth, in open sunny locations (Ali 1992). It has a cosmopolitan distribution. Although it is known from many parts of the world, it is rare in Lake Nasser. This species often grows on calcareous sand at lake edges (Belal *et al*. 1992). The presence of the species was reported in 1972-73 by Entz (1980b) but misidentified as *Chara* sp.

11- *Myriophyllum spicatum* L. This species is often described as an invasive species, and it is loosely accepted that invasions are frequently followed by rapid concomitant displacement of native species (Smith & Barko 1990). *Myriophyllum spicatum* has been discovered in the Nile valley during the past decade and its rapid colonisation seems to be influenced by changes in the Nile water regimes after the building of the AHD (Fayed 1985).

Optimal growth of *Myriophyllum spicatum* occurs in alkaline (hard-water systems) with concomitantlly high concentrations of dissolved inorganic carbon (Spence 1967, Hutchinson 1957 and Stanley 1970). Smith & Barko (1990) point out that water alkalinity provides a simple, but useful measure of the growth potential of *Myriophyllum spicatum.* This species appeared in Lake Nasser in 1993, probably introduced into the Lake through fishing nets contaminated with this hydrophyte, which were previouslly used in the Nile downstream (personal communication, Ali 1998).

Belal *et al.* (1992) classify the above mentioned species into two groups:
a. Cosmopolitan species. *Potamogeton crispus, P. pectinatus, Najas marina* subsp. *armata, Zannichellia palustris* and *Nitella hyalina* are recorded worldwide, including a range of countries in North Africa and Middle East (CAI, Andrews 1965, Mouterde 1966, Dandy 1937, Quézel & Santa 1962, Triest 1988, Van Vierssen 1982). Their presence in Upper Egypt is to be expected, but became abundant in this area as a result of new or modified habitats due to the construction of the Aswan High Dam (Belal *et al.* 1992).

b. Subcosmopolitan species. *Potamogeton trichoides* has long been known from Western North Africa and East Africa (Dandy 1937, Maire 1952), as well as Turkey and Palestine (Dismore 1933), Syria and Lebanon (Mouterde 1966). *Vallisneria spiralis* is more typically a tropical/subtropical species (Lowden 1982), rare in Africa as a whole, but associated with the Nile system (El-Hadidi 1968). *Najas horrida* occurs throughout tropical Africa and Madagascar (Triest 1988).

Changes in the macrophyte flora of Egyptian Nubia over the time

Historically, Lower Egypt has been considered the hub of freshwater macrophytes distribution in Egypt as shown by the prevalence of herbarium records in CAI and literature records (e.g. Simpson 1932, Täckholm & Drar 1950, Täckholm 1974). Intensive botanical surveys of the Nile Valley in Egyptian Nubia prior to its inundation by Lake Nasser, revealed the presence of a limited number of aquatic macrophytes species (euhydrophytes) (Table 39).

In Lake Nasser, during 1963-1964, Boulos (1966) recorded *Alisma gramineum, Damasonium alisma* Mill var. *compactum* Michell, *Potamogeton crispus, Potamogeton pectinatus, Zannichellia palustris* and *Potamogeton perfoliatus* (which was a new record). In 1972, *Potamogeton pectinatus* (Entz 1976), and in 1973-1974 *Najas marina* subsp. *armata, N. horrida, Z. palustris* and *Potamogeton pectinatus* were recorded (El-Hadidi 1976, Entz 1980b). In 1981-1982 Springuel (1985b) recorded *Najas marina* subsp. *armata, Najas horrida, Potamogeton trichoides, P. crispus, Zannichellia palustris, Vallisneria spiralis* and *Potamogeton lucens* (which was identified as *P. nodosus*).

During 1980-1986 Springuel & Murphy (1991) recorded 9 species of euhydrophytes (Table 39). *Najas armata* and *N. horrida* were abundant in the shallow waters along both shorelines of the Lake, abundantly associated with *Vallisneria spiralis.* Less commonly associated with *Najas-Vallisneria* community were *Zannichellia palustris, Potamogeton trichoides* and *P. crispus.* In contrast *V. spiralis* showed pronounced increase mainly in the mid sector of the Lake during the study period. *Zannichellia palustris* and *Potamogeton* species tended to

be most abundant in the southern sector of the Lake (>200 km south AHD), even raplacing *Najas* spp. as dominants at several sampling stations in this sector. One reason for this vegetation change may be that this upstream end of the Lake is close to sources of propagules inflowing from the Sudanese River Nile. The somewhat higher species diversity of sites at this end of the Lake (a mean of 3.6 taxa per station, compared with 2.7 for Lake Nasser as a whole) may be related to this factor. Springuel & Murphy (1991) emphasised that further studies are needed to further explain these observations as little is known at present about origins of euhydrophyte populations which have succeeded in colonising Lake Nasser.

In 1984-1986, Ali (1987) found 7 species: *N. marina* subsp. *armata, N. horrida, Potamogeton crispus, P. pectinatus, P. trichoides, Vallisneria spiralis* and *Zannichellia palustris.* In 1986, *Najas marina* subsp. *armata, N. horrida, Potamogeton crispus, P. trichoides, V. spiralis* and *Z. palustris* were recorded (Springuel 1987). In 1988-1990, Ali *et al.* (1995) recorded 6 species: *N. horrida, N. marina* subsp. *armata, Potamogeton lucens, V. spiralis, Zannichellia palustris* and *Nitella hyalina* (Table 39). The latter species was misidentified in the previous work as *Chara* sp. by Abdin (1949a) and Entz (1980b). Lake Nasser has shown a decrease in the number of species present, especially those which are not tolerant to extreme fluctuations in water level, *Ceratophyllum demersum* is one species that, although present downstream of the Dam, has never been recorded in Lake Nasser either before or after the Dam construction.

Subsequent to the construction of the Aswan High Dam, two euhydrophytes disappeared from the region (*Alisma gramineum* Lejeune and *Damasonium alisma* Mill. var. *compactum* (CAI). However, it seems that another four species have colonized the Lake, with varying degrees of success (Table 39). The current dominants are the macrophyte flora *Najas* spp. and these species which occurred in Nubian waters pre- 1964. *Potamogeton crispus* and *P. pectinatus* are common species in the River Nile and Aswan Reservoir, but now appear to be absent from Lake Nasser (Ali 1992). *Zannichellia palustris* remains confined to the area of the Nile Valley now filled by Lake Nasser, but *Vallisneria spiralis* is a fairly common plant in water bodies throughout Egyptian Nubia (Belal *et al.* 1992).

The construction of the Aswan high Dam, with the subsequent creation of new modified aquatic habitats for macrophyte growth in Egyptian Nubia, had a profound effect on the aquatic flora of the region. Although Lower Egypt probably retains, at present, its status as the more important area for aquatic plant growth, there is now a strong evidence for the existence of trends of increasing diversity and abundance of the freshwater macrophyte flora in Upper Egypt. (Belal *et al.* 1992).

Table 39 **Freshwater submerged macrophytes (flowering and non-flowering) species recorded in Egyptian Nubia pre- and post- completion of the Aswan High Dam (1962-1993).[Plates 1-5]**

Species	Boulos (1966)	El-Hadidi (1976)	Abdallah *et al.* (1972)	Entz (1976)	Springuel & Murphy (1991)	Ali (1987)	Ali (1992)	Ali (1998)
	1963-64	1963-64	1962-64	1972-74	1980-86	1984-86	1989-91	Personal communication
Alisma gramineum	+	+	-*	-	-	-	-	-
Damasonium alisma	+	+	-	-	-	-	-	-
Potamogeton crispus	+	+	+	-	+	+	+	+
Potamogeton pectinatus	+	+	+	+	+	+	-	-
Potamogeton perfoliatus	+	+	+	-	-	-	-	-
Potamogeton trichoides	-	-	-	-	+	+	-	-
Potamogeton lucens	-	-	-	-	-	-	+	+
Potamogeton nodosus	-	-	-	-	+**	-	-	-
Zannichellia palustris	+	+	+	-	+	+	+	+
Vallisneria spiralis	-	+	-	+	+	+	+	+
Najas minor	-	-	-	-	+	-	-	-
Najas horrida	-	-	-	-	+	+	+	+
Najas marina	-	+	-	+	+	+	+	+
Chara sp. (misidentification)	-	-	-	+	+	-	-	-
Nitella hyalina (macroalga)	-	-	-	-	-	-	+	+
Myriophyllum spicatum	-	-	-	-	-	-	-	+

* = not recorded ** absent by 1986

Succession of macrophyte species and community distribution in Lake Nasser (1988-1990)

Studies on Lake Nasser showed that it is a fairly hard-water, eutrophic lake. It seems that several of the euhydrophyte species present are associated with eutrophic conditions, including *Zannichellia palustris,* and *P. crispus.* Others, including *Vallisneria spiralis* and *Najas* spp., may be less well adapted to survival in the productive environment of Lake Nasser, where competition-tolerance strategy traits will be an advantage (Springuel & Murphy 1991).

Springuel & Murphy (1991) studied the seasonal growth and distribution of euhydrophytes in Lake Nasser and River Nile, and pointed out that *Najas horrida, N. armata* and *Potamogeton pectinatus* displayed a spring/summer decline in abundance with autumn and winter peaks of production. Furthermore the depth distribution in the Lake showed differential colonisation of different zones by individual species. The shallow zone in the Lake (0-0.5 m) was preferentially occupied by *Zannichellia palustris,* in the areas where this species was present (approximately 27% of the Lake shoreline). The less common *Potamogeton pectinatus* and *P. trichoides* occurred preferentially at intermediate depths (0.51-1.00 m). However, these species also occurred within this zone with *P. trichoides* penetrating, at a few sites, as deep as 1.5 m. The remaining species which include the principal dominants of the Lake macrophyte community, occur in all depths from the surface to 3.00 m. No species preferentially occurred in water deeper than 1.00 m in Lake Nasser.

Records of the euhydrophytes at 16 sites along the Lake (Fig. 66 and Table 40) between 1988 and 1990 indicated the dominance of *Najas marina* subsp. *armata* and *Najas horrida. Potamogeton lucens,* found in Lake Nasser only at Kalabsha, was previously incorrectly identified as *P. nodosus* (Springuel 1985b, Springuel & Murphy 1991).

Effect of water level on aquatic macrophytes of Lake Nasser

Habitat disturbance appears to be an important factor influencing the macrophytes of Lake Nasser with the fluctuations of the water level being the most important factor. Springuel *et al.* (1991) carried out a comparative study on the species composition and growth of aquatic macrophytes in Lake Nasser, Aswan Reservoir and the River Nile itself, downstream of the old Dam, as they have major differences in physical conditions, notably in water level and fluctuation regime. In Lake Nasser there is an annual cycle of water level change related to the seasonal flood pattern of the River Nile. In Aswan Reservoir, mean monthly water levels are relatively constant, although there is a diurnal range of about 3 m related to the daily pattern of inflow through the High Dam turbines.

Table 40 **Dry weight standing crop (g/m²) of euhydrophytes in shallow and deep water zones during 1989 at 16 sites in Lake Nasser at various sampling times (Ali 1992).** [For localities refer to Fig. 66].

Zones & Species	Soliman	Mariya	Kalabsha (b)	El-Birba West	El-Birba East		Mirwaw West	Mirwaw East	Amada	Abu Hor		Kalabsha (a)	El-Madiq	Turgumi			
	16 Feb.	**17 Feb.**	**1 Oct.**	**11 May**	**11 May**	**2 Oct.**	**14 Feb.**	**14 Feb.**	**7 Sept.**	**12 Feb.**	**11 Feb.**	**6 Sept.**	**6 Sept.**	**4 April**	**1 Jan.**	**10 Oct.**	**3 Mar.**
Shallow Zone																	
N. marina	0.4	0.114	-	3.242	-	-	-	-	-	0.2	0.49	-	-	4.288	16.36	-	-
N. horrida	-*	-	-	-	-	-	1.127	10.86	-	-	-	-	0.005	-	-	-	-
Z. palustris	-	0.252	-	-	-	-	0.34	0.29	-	0.005	0.027	-	-	-	-	-	-
Deep Zone																	
N. marina	1.55	3.51	16.263	12.53		0.011	1.171	3.94	-	2.801	0.81	0.04	0.331	1.0	13.46	7.192	31.591
N. horrida	-	-	0.094	4.41		28.11	-	-	0.963	-	-	4.563	0.045	-	-	-	-
Z. palustris	-	-	-	-		-	0.199	-	-	0.373	-	-	-	-	-	-	-
V. spiralis	-	-	0.008	-		-	-	-	5.423	-	-	-	0.803	-	-	-	-
P. lucens	-	-	3.899	-		-	-	-			-	-	-	-	-	-	-

***(-)=not recorded**

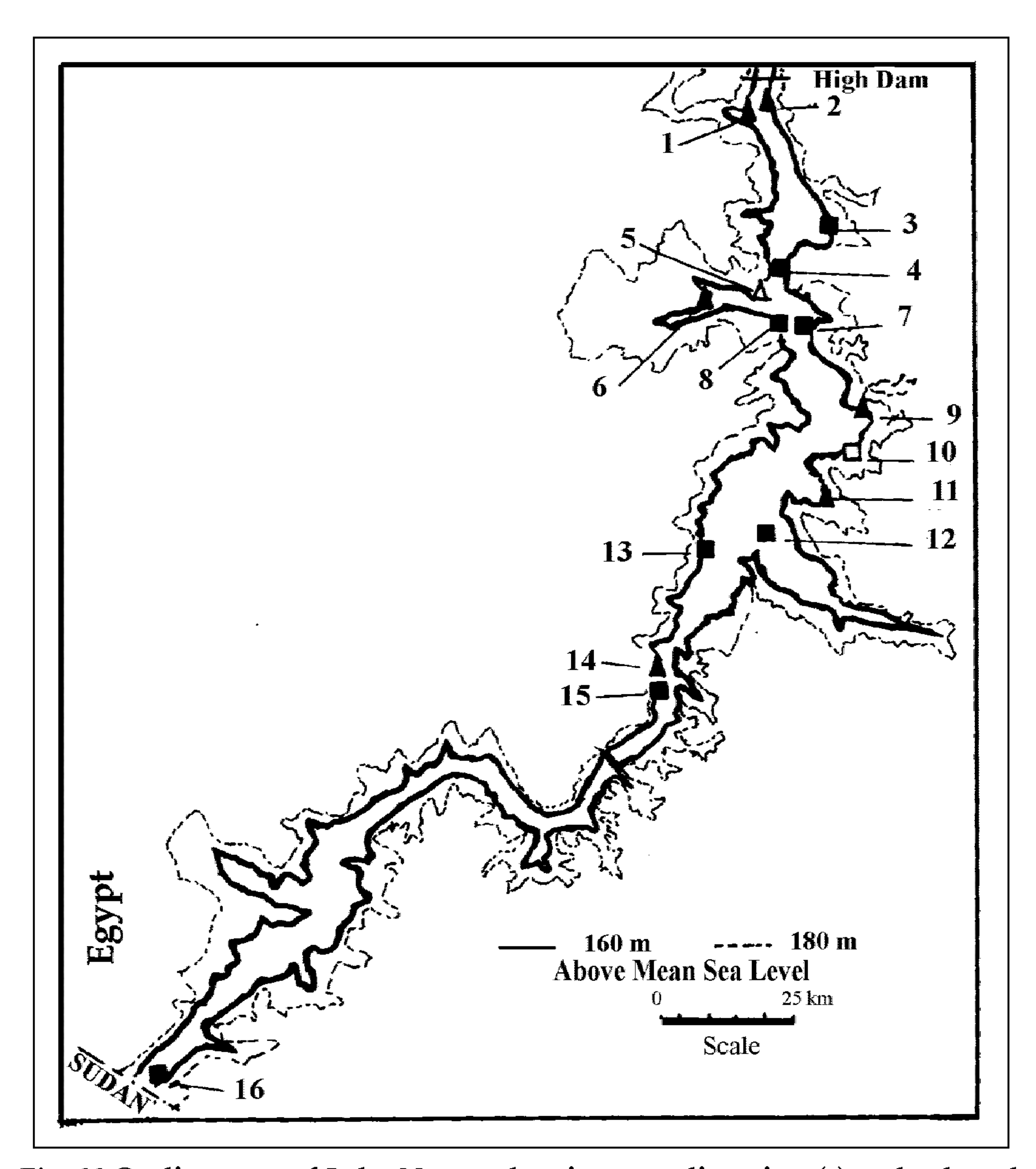


Fig. 66 **Outline map of Lake Nasser showing sampling sites (▪) and selected sites used (▲), 1: El-Birba West, 2: El-Birba East, 3: Abisco, 4: Abu Hor, 5: Kalabsha (a), 6:Kalabsha (b), 7:Mirwaw East, 8:Mirwaw West, 9: Soliman, 10:Mariya, 11:Turgumi, 12: Allaqi, 13:Kourta II, 14:Amada, 15:El-Madiq, 16:Adindan (Ali 1992).**

There were major differences in community dominance between the three systems. *Najas marina* subsp. *armata* dominated the highly disturbed littoral zone of Lake Nasser, making up nearly 40% of the total standing crop. Other species present were *Najas horrida, Vallisneria spiralis* and Charophyta. However, in both Aswan Reservoir and River Nile, the dominant species were *Ceratophyllum demersum* (comprising 59-78% of total standing crop) and *Potamogeton crispus* (15-20% of total crop). In terms of relative standing crop

these species virtually excluded all others from the reservoir, but in the river approximately 25% of the total submerged standing crop was made up of other species, notably *Potamogeton perfoliatus* and *Myriophyllum spicatum*. It is suggested that the High Dam represents a major vegetation boundary in the River Nile ecosystem.

Ali *et al.* (1995) found that peak growth in the shallow water zone tended to occur following inundation or reinundation of sites by rising water levels, following exposure of sites. This produced a discontinuous distribution, over the time, of short established-phase submerged macrophytes, with a long period when no plants are present. In contrast macrophytes are always present in the deeper zone. There are geographical differences in distribution. *Najas horrida* was dominant in the northern section of the Lake (El-Birba - Fig. 66). Further south, *Najas marina* dominated the aquatic community at Turgumi and Kalabsha (in the middle section of Lake Nasser). At the southernmost site, Amada (west bank) *Najas* spp. were largely replaced by *Vallisneria spiralis,* as a dominant species, occurring at the only site with a fine sand hydrosoil. In May 1989 *N. marina* subsp. *armata* became more abundant and reached its highest biomass of 507.44 g/m^2 (Table 41).

Table 41 **Dry biomass (g/m^2) of euhydrophytes and macroalgae in the shallow water zone at Turgumi, Lake Nasser (Ali 1992).**

Species	April 1989	May 1989	July 1989	May 1990
Najas marina	114.87	507.44	120.94	47.93
Najas horrida	---	---	---	50.37
Nitella hyalina	103.12	54.30	---	37.55
Zanichellia palustris	---	---	---	1.25

ALGAE

PHYTOPLANKTON

The formation of Lake Nasser was accompanied by structural and physico-chemical changes which consequently affected the river biota. These changes lead to corresponding qualitative and quantitative alterations in the composition of the phytoplankton community.

Species Diversity

The community of planktonic algae in Lake Nasser is fairly diverse, belonging mainly to four divisions: Chlorophyta, Bacillariophyta, Cyanophyta and Pyrrophyta. Samaan (1971) recorded 27 species, while Latif (1974b) mentioned only 20 species. Zaghloul (1985) recorded 43 species, while Mohamed, *et al.* (1989) recorded 50 species belonging to the four divisions (Table 42).

Table 42 **Inventory of phytoplankton species recorded from Lake Nasser from 1981 to 1993. [PLATES 6-12]**

Taxa & Species	1981 Zaghloul (1985)	1982/84 Mohammed, *et al* (1989)	1993 Abdel-Monem (1995)
CHLOROPHYCEAE			
Palmellaceae			
Asterococcus limneticus (Cienkowski) Scherffel	-	-	+
Chlamydocapsa planctonica W. & G.S.West (=*Gloeocystis planctonica* G.gigass Kütz. Lage)	-	+	+
Coelastraceae			
Chlorococcum aegyptiacum **Archibald** (=***Cholorella*** **Beijerinck**)	-	-	+
Coelastrum microsporum **(Nägeli) var.** ***microsporum*** (=***C. robustum*** **Haz. 1964,** ***Chlorella regularis*** **Oltm 1904**)	-	+	+
C. reticulatum (Dangeard) seen var. *reticulatum* (= *C. distans* Turn. 1982)	-	-	+
Desmidiaceae			
Cosmarium contractum **(Kirchner)**	-	-	+
C. depressum **Lundell**	-	+	-
C. subtumidum **Nadst.**	+	-	-
Staurastrum paradoxum **Meyen**	+	-	+
S. tetracerum **Ralfs**	-	-	+
S. uniseriatum **Nyg.**	-	+	-
Closterium venus **Kütz.**	-	+	-
Dictyosphaeriaceae			
Dictyosphaerium elegans **Bachmann**	-	-	+
D. ehrenbergianum **Nägeli**	-	-	+
D. pulchellum **Wood**	+	+	+
D. subsalitarium **Van Goor** (=***Dictyosphaerium primarium*** **=** ***D. simplex*** **Skuja**)	-	-	+
Micractinaceae			
Golenkinia radiata Chodat	-	+	+
Oocystaceae			
Ankistrodesmus falcatus (Corda) Ralfs	+	+	+
A. fusiformis Corda	-	-	+
Lagerheimia citriformis (Snow) G.M.Smith (=*Chodatella citriformis* Snow)	-	-	+
L. ciliata (Lager.) Chodat. (= *Chodatella ciliata* Lagerh. Lemm.)	-	+	+
L. longiseta (Lemm.) Wille (=*Chodatella longiseta* Lemm.)	-	-	+
L. quadriseta (Lemm.) G.M. Smith	-	-	+

(=*Chodatella quadriseta* Lemm.)			
L. subsalsa Lemm.			
(=*Chodatella susbsalsa* Lemm.)	-	-	+
Monoraphidium minutum (Nägeli) Komm. Leg.			
(= *Selenastrum minutum* Nag. Collins)	-	-	+
M. contortum (Thuret) Komm.			
(=*Ankistrodesmus falcatus* var. *duplex* Kütz.	-	-	+
=*A. f.* var *spirilformis* G.S. West)			
M. convolutum (Cord) Komm.			
(=Ankistrodesmus convulutus *Corda)*	-	-	+
M. griffithii Berk. Komm.			
(=*Ankistrodesmus acicularis A.* Braun.	-	-	+
Korsh. = *A. f.* var *acicularis* Braun)			
M. komarkovae Nygaard	-	-	+
(=*Ankistrodesmus facatus.* var *setiformis* Nyg.)			
Oocystis sp.	+	-	-
Oocystis lacustris Chodat	-	-	+
O. borgei Snow	-	+	+
O. elliptica W. West	-	-	+
O. parva W. & G. S. West	-	-	+
Closteriopsis longissima Lemm.	-	+	+
Franceia sp.	-	+	-
Kirchneriella microscopica Nyg.	-	+	-
Tetraedron minimum (A. Br.) Hansg.	-	+	-
Hydrodictyaceae			
Pediastrum duplex Meyen	-	+	-
Pediastrum duplex var. *gracillium* W. & G. S. West	-	-	+
P. simplex Meyen	+	+	+
(= *P. clathratum* Sch. Lemm.)			
P. simplex var. *biwaense* Fukush.	-	-	+
P. simplex var. *radians* Lemm.	+	-	-
P. boryanum (Turipn) Menegh.	+	-	-
Planktosphaeria gelatinosa G.M.Smith	-	-	+
Characiaceae			
Schroederia setigera (Schroed.) Lemm.	-	+	-
Scenedesmaceae			
Crucigenia quadrata Morren	-	+	-
Scenedesmus arcuatus Lemm.	-	+	-
S. bijugatus (Turp.) Kütz.	+	-	-
S. diamorphus Turp.	+	-	-
S. quadricauda (Turp.) Brèb.	+	+	-
S. obliquus (Turp.) Kütz.	-	+	-
Actinastrum hantzschii Lagerh	+	-	-
Zygnemataceae			
Spirogyra Link.	+	-	-
--			
	-	+	+
	-	+	-
	+	-	+
	+	+	-
	-	+	-
Chroococcaceae			
Chroococcus minutus (Kütz.) Näegeli	-	-	+

C. dispersus (Keissler) Lemmermann	+	-	+
C. limnetica Lemm.	-	+	+
C. turgidus (Kütz.) Nägeli	-	-	+
Dactylococcopsis sp.	-	+	-
D. acicularis Lemm.	+	-	-
Gomphosphaeria lacustris Chodat (=*G. littoralis* Hayren)	+	+	+
G. lacustris var. *compacta* Lemm. (= *G. compacta* Lemm.Strom.)	-	-	+
Merismopedia warmingiana Legerheim (=*M. tenuissima* Lemm.)	-	-	+
M. minima Beck.	-	-	+
M. punctata Meyen.	+	-	+
M. tenuissima Lemm.	-	+	-
Microcystis aeruginosa Kütz (= *M. flos-aquae* Witt. Kir.)	+	-	+
M. wesenbergii (Komarek) Starmach	-	+	-
M. elachista W. & G. S. West Starmach (=*Aphanocapsa elachista* W. & G. S. West)	+	-	+
M. grevillei Hassal Elenkin (=*Aphanocapsa gravillii* Hass Kabenhorst)	-	-	+
M. rainbaldii Richter Forti (=*M. holsatica* Lemm. = *M. pulverea* Wood Forti = *M. p.* var. *incerta* Lemm. Crow = *Aphanocapsa delicatissima* W. & G. S. West)	-	-	+
Oscillatoriaceae			
Lyngbya limnetica Lemm.	+	+	+
Lyngbya sp.	-	-	+
Oscillatoria limnetica Lemm.	+	-	+
O. planctonica Wolosz.	+	-	+
Oscillatoria. sp.	-	+	+
Phormidium africanum Lemm.	-	-	+
P. mucicola Naum. & Huber.	-	-	+
P. tenue (Menegh.) Gom.	-	-	+
P. corium (Ag.) Gom.	-	-	+
Phormidium sp.	-	+	-
Spirulina laxissima G.S. West	+	-	-
Spirulina sp.	-	+	-
BACILLARIOPHYCEAE			
Coscinodiscinaceae			
Aulacoseria muzzanensis Meister Krammer (=*Melosira muzzanensis* Meister = *M. granulata* var *muzzanensis* Bethge)	-	-	+
A. granulata Ehre. Simonsen. (=*M. granulata* (Ehr.) Ralf = *M. lineolata* Gru.)	+	-	+
A. g. var. *angustissima* O. Müller Simonsen (=*M. g.* var. *angustissima* O. Müller)	+	-	+
A granulata. var. *valida* Hust.	-	-	+
Cyclotella ocellatus Pantocsek	-	-	+
C. glomerata Bachmann	-	-	+
C. kützingiana Thwaites	-	+	+
C. meneghiniana Kütz.	+	+	+
Melosira agassizii Ostef var. *malayensis* Hust.	-	-	+

M. nyassensis O. Müller	-	-	+
M. nyassensis var *victoriae* O. Müller	-	-	-
M. distans var. *distans* (Ehr.)	-	-	+
M. granulata (Ehrbg.) Ralfs	+	+	-
Stephanodiscus aegyptiacum Ehr. (*S. nana* Meister)	-	-	+
Fragilariaceae			
Synedra ulna Ehrbg.	+	+	+
S. tabulata (Ag.) Kütz.	+	-	-
Naviculaceae			
Diploneis sp.	-	+	-
Gyrosigma attenuatum (Kütz) Rabenh.	-	+	-
Navicula pupula Kütz.	-	+	-
N. radiosa Kütz.	-	+	-
Navicula sp.	+	+	-
Pleurosigma elongatum Sm.	+	-	-
Achnanthineae			
Cocconeis placentula Ehrbg.	+	-	-
Gomphonemataceae			
Gomphonema lanceolatum Ehrbg.	-	+	-
Amphora ovalis Kütz.	+	+	-
Cymbellaceae			
Cymbella tumidae (Bréb) van Heurk	+	+	-
Epithemia sorex Kütz.	-	+	-
Epithemia gibbrula Ehrbg.	+	-	-
Rhopalodia sp.	-	+	-
Nitzschiaceae			
Nitzschia microcephala (Grun.)	+	-	-
N. palea (Kütz.) W. Sm.	+	-	-
N. apiculata Greg.	+	-	-
Surirellaceae			
Surirella ovalis Bréb.	+	-	-
DINOPHYCEAE (PYRRHOPHYTA)			
Ceratiaceae			
Ceratium furcoides (Levander) Langhans (= *C. hirudinella* var. *furcoides* Levander)	-	-	+
C. hirundinella Bergh.	+	+	+
C. cornutum (Ehr.)	-	-	+
Gymnodiniaceae			
Gymnodinum lantzchii Útermöhl.	-	-	+
Peridiniaceae			
Peridinium africanum Lemm. Lif. (=*P. intermedium* Thompson = *P. cinctum* O.F. Müller)	-	-	+
P. inconspicüm Lemm. F. Armatum	-	-	+
P. pigmeum (Lin.) Baurrelly	-	-	+
P. wierejskii Woloszynska	-	-	+
P. willei Huitfeld-Kass	-	-	+
Peridinium. sp.	-	+	-
Peridiniopsis pygmaium (Lin.) Bourrelly	-	-	+
Glenodiniaceae			
Glenodinium sp.	+	-	-
EUGLENOPHYCEAE			
Euglena acus Ehr.	+	-	-

Note: Mohamed, I. (1993g) recorded also the genus *Microcystis* sp. (Cyanophyceae).

In 1993 Abdel-Monem (1995) recorded 84 planktonic algal species including 35, 23, 15 and 11 species of Cyanophyceae, Chlorophyceae, Bacillariophyceae and Dinophyceae, most of these were not recorded by previous investigators (Table 42). Although the number of species is high, only a limited number formed the main bulk of phytoplankton communities. Green algae contributed more genera to the phytoplankton than any other group. However, diatoms and blue-green algae were found to be alternatively the dominant groups. These two dominant groups exhibited seasonal, local and vertical variations along the main body of the Lake.

The total number of phytoplankton species recorded from Lake Nasser during the period 1981-1993 (Table 42) is 135 species belonging to five classes: 54 spp. of Chlorophyceae, 34 spp. of Cyanophyceae, 33 spp. of Bacillariophyceae, 13 spp. of Dinophyceae and 1 sp. of Euglenophyceae.

The components of the plankton community are comparable to those in the White Nile between Khartoum and Gebel Aulia Dam (Brook & Rzóska 1954, Talling 1957a, Abu-Gideiri 1969, Talling 1976b), the Blue Nile (Talling & Rzóska 1967), some Central East African waters such as Lake Kyoga (Evans 1962), Lake Victoria (Talling 1957b and 1976b) and Lake Belwood (Duthie 1968).

Phytoplankton Standing Crop

The phytoplankton community in Lake Nasser is rich both in numerical density and biomass.

Density. Numerically, Bacillariophyceae and Cyanophyceae are the main components, while Dinophyceae, Chlorophyceae and Euglenophyceae persisted as frequent or rare forms. Thus, in 1993 Abdel-Monem (1995) found that the annual averages of Cyanophyceae ranged from a maximum of 83.7% forming a major peak in autumn and a minimum of 21.8 %, in winter. Following the Cyanophyceae, Bacillariophyceae constituted 76.7 % of the total crop in winter, and a minimum (13.3 %) in autumn. Chlorophyceae occupied the third predominant group with population densities ranging from 20.6 % in spring to a minimum of 2.1 % in winter. Dinophyceae being the least represented in number of species and density, they ranged from 1.4 % in spring to nil in winter.

Samaan & Gaber (1977) mentioned that because the flood-affected regions of the Lake exhibit different characteristics from the areas beyond the reach of the flood, the phytoplankton was different in terms of number and types at different periods of the year. Gaber (1982) pointed out that in October

1979 Cyanophyceae constituted 81.23 % of the total phytoplankton community (average $2.52x10^6$ algal units/l), while Bacillariophyceae formed 13.86% by number (average $0.43x10^6$ algal units/l). The percentage of Cyanophyceae increased from the High Dam to Amada (91.72 %), and reached its maximum value (95.57 %) in Khor Singari. Then it decreased gradually from Tushka to Adindan where it reached 31.05%. The average number of diatoms remained low between the High Dam and Amada, but showed a rapid increase from Tushka to Adindan (Gaber 1982). Chlorophyceae in the Lake remained low, as they constituted only about 4.9 % by number of the total phytoplankton (average $0.152x10^6$ units/l). Generally, Chlorophyceae were concentrated in the northern part of the Lake. The highest percentage was observed in Khor Kalabsha and decreased in the southern part and reached the least percentage in Tushka ($0.054x10^6$ algal units/l) and in Khor Or ($0.016x10^6$ algal units/l) (Gaber 1982). The Dinophyceae were rarely represented in the Lake by *Peridinium* sp. and in average numbers of 500 unit/l, contributing only about 0.01% of the total community (Gaber 1982).

Latif (1984b) showed that in March and August 1976, the phytoplankton in Lake Nasser, was in the range of 3.2 to 11.5 $x10^6$ algal units/l and 4.7 to $9.5x10^6$ algal units/l respectively (Fig. 67). Variations in the number and percentage of phytoplankton at different stations along the main channel of Lake Nasser (1976) show that the northern 100 km had a higher number of phytoplankton in August than in March (Latif, 1984b -Fig. 67). At the same time, the central part of Lake Nasser, extending from El-Madiq to Amada, did not show great changes in the number of phytoplankton cells. The region from Tushka to Adindan showed the widest difference. The latter author pointed out that during flood time (August) flood waters push ahead great amounts of phytoplankton to the northern part of the Lake, thus resulting in the highest figures recorded throughout the year. Nevertheless, due to riverine conditions, Adindan presented lower values in August than in March.

Latif (1984b) pointed out that in August 1976, cyanophytes were the most common, as their percentage ranged from 87.4 to 96.4% (average 94.3%); while diatoms formed only 2.7% (range 1.1 to 9.0%). From the High Dam to Amada, cyanophytes were more common than diatoms and their percentage varied from 71.2 to 89.0%. However, at Tushka and Adindan, cyanophytes comprised a very small percentage, i.e. only 7.0 and 0.9%, respectively, and in contrast diatoms constituted the major part of phytoplankton forming 92.3 and 98.6%, respectively (Latif 1984b). Chlorophytes did not show wide differences and were of low magnitude, i.e. 0.5 to 3.0% of the total numbers in March, and 2.2 to 3.6% in August. Thus, in the post-flood season, diatoms form the most common phytoplankton in the areas affected by the flood (Fig. 67-Latif 1984b).

Based on the observations of Zaghloul (1985) and Abdel-Monem (1995) the specific variations of phytoplankton in Lake Nasser may be summarized as follows:

1- The standing crop of phytoplankton tended to increase southwards from $3.405x10^6$ algal units/l at El-Birba to $15.272x 10^6$ algal units/l at Adindan.

2- The density of the phytoplankton standing crop was $6.258x10^6$ algal units/l in the surface water. This value decreased to $2.08x10^6$ algal units/l at 20 m depth (Zaghloul 1985). These values coincide with those obtained in 1993 by Abdel-Monem (1995) who showed that the average seasonal annual density at subsurface waters was of $1.017x10^6$ and $0.918 x10^6$ algal units/l at 15m depth and $0.984 x10^6$ near the bottom at 6 sites in the main channel. It seems that the difference in density in different years may be attributed to the limited number of samples collected at different localities.

3- Bacillariophyceae contributed 50.06% by number to the total phytoplankton. They were represented mainly by *Melosira* sp., which constituted numerically over 99% of the total diatoms. Other genera of frequent distribution included *Synedra* and *Nitzschia* spp. Seven species were of rare occurrence (Zaghloul 1985). Abdel-Monem (1995), however, pointed out that diatoms in the main channel were mainly represented by *Aulacoseria granulata, Aulacoseria granulata* var. *angustissima, Melosira nyassensis* var. *victoriae* and *Cyclotella ocellatus.* Other species of infrequent occurrence were: *Aulacoseria muzzanensis, Melosira agassizii, Cyclotella meneghiniana* and *C. glomerata.* Most of these species were not recorded by earlier authors.

4- The seasonal variations of Bacillariophyceae varied between the northern and southern sectors as well as in the khors. Generally, their maximum frequency was recorded in the southern region of the Lake in summer.

5- Cyanophyceae contributed numerically 47.45% of the total phytoplankton, with annual averages of $3.146x10^6$ algal units/l in the surface water and $0.813x10^6$ algal units/l at 20 m depth. *Anabaenopsis* was the dominant genus constituting about 93.41% of the total cyanophytes. Other genera with frequent occurrence comprised *Dactylococcopsis, Microcystis* and *Merismopedia* spp. In 1993 the main species recorded by Abdel-Monem (1995) were *Microcystis aeruginosa, Chroococcus limnetica, Lyngbya limnetica, Oscillatoria limnetica* and *Phormidium africanum.* The less abundant species were *Chroococcus minutus, Merismopedia punctata, Microcystis grevillei, Oscillatoria planctonica* and *Phormidium tenue.*

Glenodinium sp. was the main representative of Dinophyceae. Its main occurrence was confined to Khor Kalabsha in spring. Abdel-Monem (1995) reported that Dinophyceae were very rare in 1993 and contributed about

$0.6x10^4$ algal units/l representing 1.08% of the total phytoplankton crop. Their maximum occurrence was recorded in spring and summer while they were not recorded in winter.

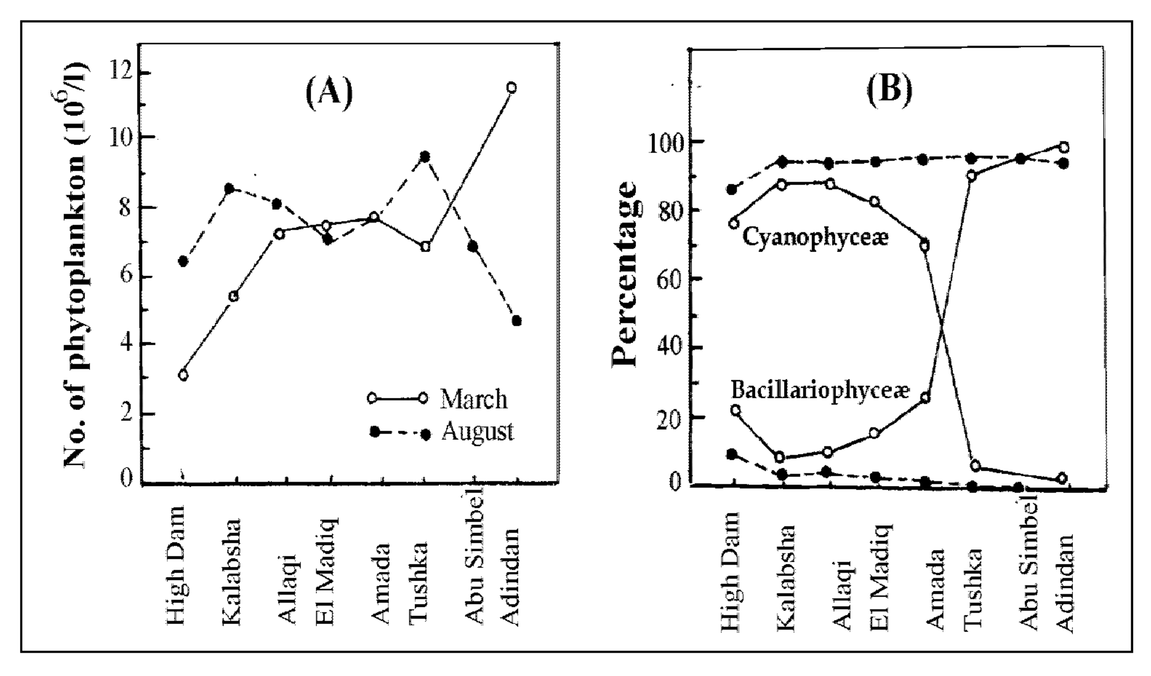


Fig. 67 **Phytoplankton at different stations along the main channel of Lake Nasser in March and August 1976. A: number of phytoplankton (10^6/l), B: percentage of Cyanophyceae and Bacillariophyceae (Latif 1984a).**

7- Chlorophyceae contributed 0.43% of the total phytoplankton crop in the Lake and consisted mainly of *Pediastrum* and *Staurastrum* spp. In 1993 Abdel-Monem (1995) showed that green algae formed numerically about $6.4x10^4$ algal units/l representing 7.88% of the total phytoplankton crop. Their highest density was recorded in spring ($16.9x10^4$ algal units/l, 20% of the total count), and the lowest density in winter ($1.9x10^4$ algal units/l, 2.1% of total count).

Mohamed, I. (1993j) investigated the seasonal changes of vertical distribution of phytoplankton in the main channel of Lake Nasser and found that diatoms of genus *Melosira* contribute the highest number of cells in February, May, August and November 1990 (Fig. 69). This agrees with the observations of Zaghloul (1985).

Habib (1992b) found that in Khor El Ramla, the highest number of phytoplankton cells was recorded in August 1988 ($5.13x10^4$ units/l) and the lowest ($0.32x10^4$ units/l) in November 1986. Generally, all the stations in Khor El Ramla showed a slow increase from February to September and November (Fig. 72).

Biomass. Zaghloul (1985) summarized the biomass of phytoplankton collected from Lake Nasser as follows:

1- The phytoplankton biomass reached annual averages of 22.913 and 4.088 mg/l in the surface water and at 20 m depth, respectively. Results indicate that the biomasses of the different phytoplankton divisions were altered when compared with their numerical distribution.

2- The phytoplankton biomass increases southwards to the highest value of 45.065 mg/l at Adindan due to the increased numbers of Chlorophyceae and Bacillariophyceae. It showed also a different seasonal periodicity within the northern and southern sectors and khors, but reached its peak at most stations in spring and also at Adindan in winter.

3- Although numerous species were recorded in the Lake, yet few of them formed the main bulk of phytoplankton biomass with a specific distribution at the different localities. Thus, *Glenodinium* sp. was confined to Khor Kalabsha where it formed 95% of the total phytoplankton by weight . On the other hand, *Melosira granulata* and *Pediastrum* spp. were the main biomass components at Adindan.

Horizontal, vertical and seasonal distribution

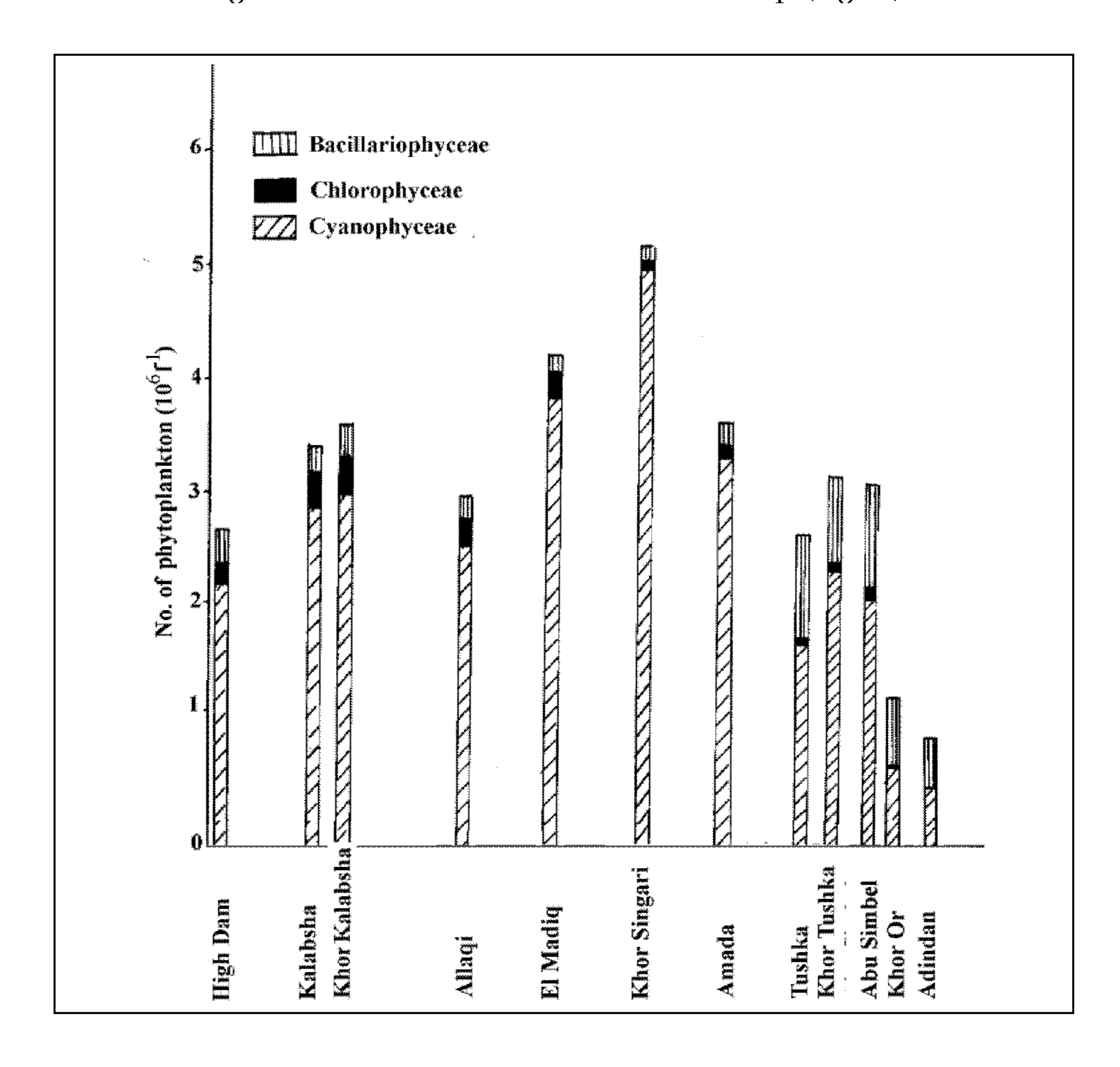
The horizontal distribution of the total phytoplankton in the upper 10 m showed a marked increase from the High Dam (average $2.708\text{x}10^6$ algal units/l) to Kalabsha (average $3.440\text{x}10^6$ algal units/l). A slight drop was recorded at Allaqi (average $2.994\text{x}10^6$ algal units/l) (Table 43 and Fig. 68 - Gaber, 1982). Another gradual increase was recorded at El-Madiq, and this was succeeded by a rapid decrease in the total number of phytoplankton southwards, reaching the lowest value at Adindan ($0.948\text{x}10^6$ algal units/l). In 1993, Abdel-Monem (1995) studied the horizontal, vertical and seasonal variations of the phytoplankton standing crop in the main channel and found that the highest seasonal average was attained in winter ($1.327\text{x}10^6$ algal units/l), followed by autumn ($1.085\text{x}10^6$ algal units/l) and spring ($0.93\text{x}\ 10^6$ algal units/l). The lowest average value was recorded in summer being $0.729\text{x}\ 10^6$ algal units/l. The maximum standing crop ($5.92\text{x}\ 10^6$algal units/l) was recorded at Dihmit near the bottom, while the lowest was found in summer ($4\text{x}\ 10^6$ algal units/l) near the bottom at Tushka.

Khors sustained higher density of phytoplankton than the main stream; their numbers increased to $3.622\text{x}10^6$ algal units/l at Khor Kalabsha and $5.234\text{x}10^6$ algal units/l at Khor Singari (Table 43 and Fig. 68 - Gaber 1982).

Gaber (1982) recorded the vertical distribution of the total phytoplankton at the different stations in October 1979 as shown in Table 43. It appears that the phytoplankton profile remained, more or less, constant at the northern section of the Lake i.e. from High Dam to Kalabsha. The distribution of phytoplankton at Amada showed relatively higher values at 3 m depth, mainly due to

Cyanophyceae. The number of phytoplankton at El-Madiq and Abu Simbel showed higher values at the surface when compared with that of the subsurface water. The maximum distribution of phytoplankton was recorded in Khor Singari at 1 m depth being 7.62×10^6 algal units/l (Gaber 1982 - Table 44).

Mohamed, I (1993j) carried out studies on the seasonal, vertical and horizontal distribution of the dominant phytoplankton species in the main channel of Lake Nasser (Figs. 69 and 70) at six stations. It was obvious that the highest number of diatoms (mainly *Melosira* sp.) was found during February and May 1990. In February 1990, *Melosira* spp. contributed the highest number of cells at all stations (Fig. 69), followed by *Oscillatoria* sp. (Cyanophyta) (Fig. 70), while *Navicula* spp. (Bacillariophyta) were found in the lowest number of cells and was recorded only at station 1 at depths 5, 10, 15 m (Fig. 70). *Staurastrum* sp. and *Ankistrodesmus* spp. (Chlorophyta) appeared at stations 2, 3 and 4 for both genera, and stations 5 and 6 for *Staurastrum* sp. (Fig. 70).



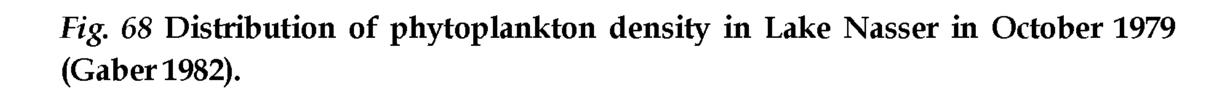


Fig. 68 **Distribution of phytoplankton density in Lake Nasser in October 1979 (Gaber 1982).**

Table 43 **Distribution of the different groups of phytoplankton (10^6 unit/l) in Lake Nasser and their percentage density to total population during October 1979 (Gaber 1982).**

Site	Cyanophyceae		Chlorophyceae		Bacillariophyceae		Dinophyceae		Total
	No.	%	No.	%	No.	%	No.	%	
High Dam	2.192	80.95	0.222	8.33	0.294	10.86	---*	---	2.708
Kalabsha	2.878	83.66	0.312	9.07	0.244	7.09	0.006	0.17	3.440
Khor Kalabsha	3.008	83.05	0.328	9.06	0.286	7.90	---	---	3.622
Allaqi	2.558	85.44	0.242	8.08	0.194	6.48	---	---	2.994
El-Madiq	3.872	90.84	0.228	5.40	0.160	3.76	---	---	4.260
Khor Singari	5.002	95.57	0.100	2.10	0.122	2.33	---	---	5.234
Amada	3.368	91.72	0.144	3.92	0.160	4.36	---	---	3.672
Tushka	1.716	62.67	0.054	1.97	0.968	35.35	---	---	2.738
Khor Tushka	4.404	74.50	0.078	2.47	0.746	23.08	---	---	3.232
Abu Simbel	2.148	67.84	0.092	2.91	0.926	29.25	---	---	3.166
Khor Or	0.652	51.34	0.016	1.26	0.602	47.40	---	---	1.270
Adindan	0.484	51.05	---	---	0.464	48.95	--	--	0.948
Average	2.523	81.23	0.152	4.90	0.430	13.86	500/1	0.01	3.107

* (--) not recorded.

In May 1990, *Melosira* sp. was recorded with the highest number of cells (Fig. 69). *Microcystis* sp. (Cyanophyta), *Cyclotella* sp. (Bacillariophyta) (Fig. 69) were represented by a high number of cells; while *Coelastrum, Staurastrum* and *Merismopedia* spp. (Figs. 69 and 70), *Peridinium* sp. and *Ceratium* sp. (Fig. 70) were recorded in the lowest number.

In August 1990, *Melosira* sp. was found in the highest number of cells and appeared at all stations except station 4 (Fig. 69). *Microcystis* sp. was recorded in all stations (Fig. 69) and *Scenedesmus* sp. only in station 1 (Fig. 70) and were present in high number of cells.

In November 1990, *Melosira* spp. and *Microcystis* spp. were recorded with the highest number of cells at all stations except station 1 (Fig. 69), while *Coelastrum* sp. was observed in high number (Fig. 70). The other genera except *Pediastrum* were found in lower number of cells (Figs. 69 and 70).

It is worth mentioning that phytoplankton in Lake Nasser revealed vertical variations during the periods of thermal stratification (late spring, summer and early autumn months). Diatoms and blue-green algae (Cyanobacteria) remained the dominant groups also in the lower layers. Moreover, *Cyclotella* sp. and *Anabaenopsis* spp. were the dominant genera in diatoms and blue-greens. Habib (1998a) pointed out that the percentage composition of blue-greens in 1991 dominated the community during spring and summer, being more tolerant to relatively high temperatures. Diatoms dominated the community once in winter (December).

Although oxygen concentration was always under the saturation level, the phytoplankton abundance in spring and summer was accompanied by high oxygen saturation levels, pH values and chlorophyll *a* concentrations (Belal *et al.* 1992). The latter authors found that the temporal course of algal development showed, more or less, the opposite trend to that of the dissolved nitrate-nitrogen (Table 45). Variations in time of the nitrate-nitrogen concentration, chlorophyll *a* and total phytoplankton populations are presented in Fig. 71.

Habib (1995c) in her investigation on the seasonal variation of phytoplankton at four stations in Khor El Ramla from September 1986 to December 1988 recorded three peaks in the total number of the population in November 1986, November 1987 and August 1988 (Fig. 72). The highest peak was recorded in August 1988 (5.13×10^4 algal units/l), and the lowest (0.32×10^4 algal units/l) in November 1986. Generally, all the stations showed a slow increase from February to September and November 1987 recording a second peak. The four stations showed the same trend of seasonal variation, recording a gradual decrease through autumn and winter. Generally, chlorophyll *a* peak always preceded or coincided with the peak of plankton numbers.

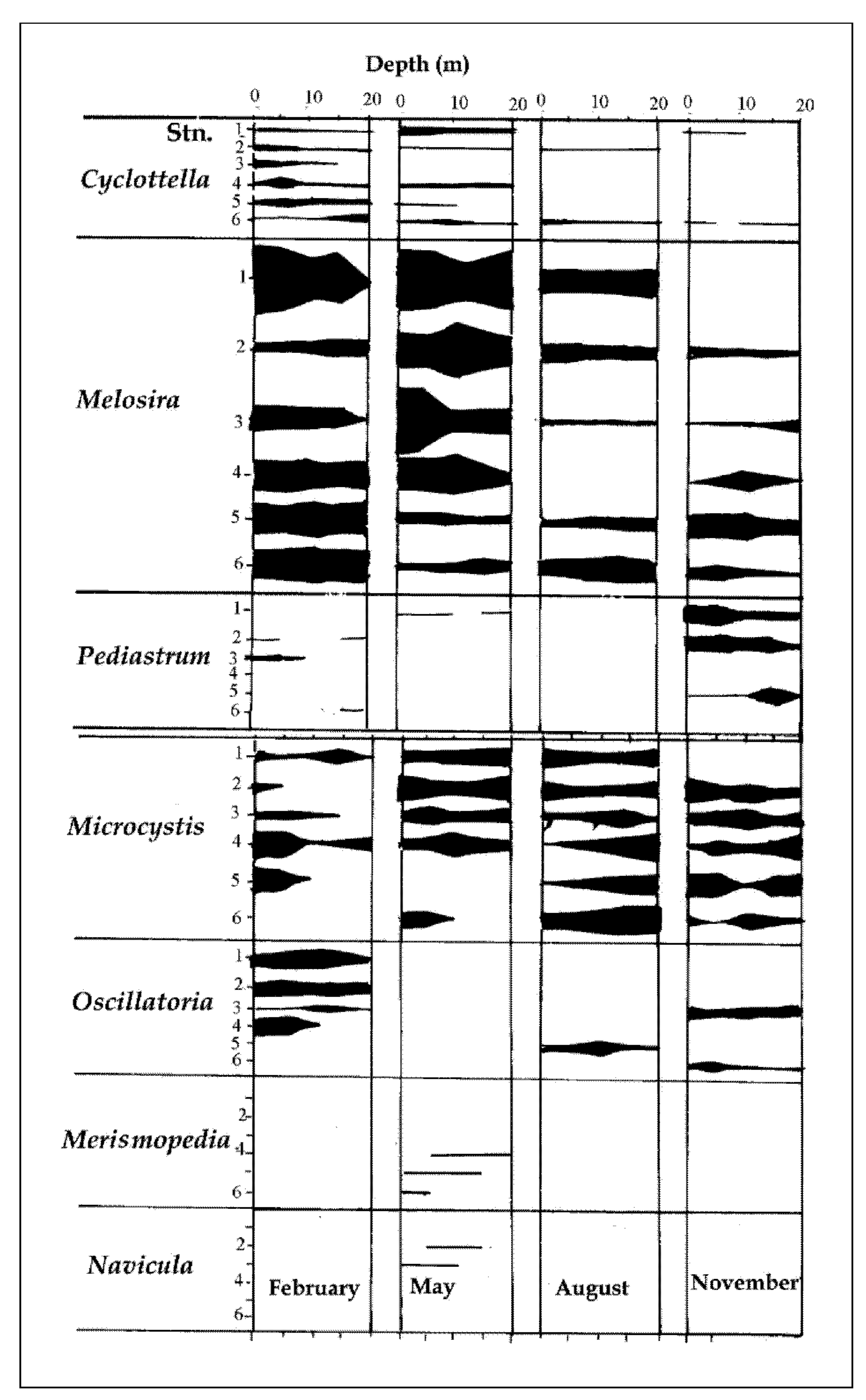


Fig. 69 **Seasonal changes of vertical distribution of phytoplankton in the main channel in 1990 (Mohamed, I. 1993j). Scale bar = 1000 cells/ml. [**For stations refer to Fig. 4**].**

Table 44 **Vertical distribution of the total number of phytoplankton (10^6 algal units/l) recorded at different stations during October 1979 (Gaber 1982).**

Site	Surface	1m	2m	3m	4m	5m	10m
High Dam	**2.945**	**2.954**	**2.660**	**2.828**	**3.010**	**2.604**	**1.946**
Kalabsha	**4.536**	**3.024**	**3.738**	**3.416**	**3.346**	**3.006**	**2.954**
Khor Kalabsha	**3.584**	**3.598**	**3.024**	**3.374**	**4.046**	**2.884**	**4.844**
Allaqi	**2.940**	**3.430**	**3.584**	**2.884**	**3.234**	**3.094**	**1.792**
El-Madiq	**5.026**	**3.808**	**4.186**	**4.920**	**3.920**	**3.962**	**4.550**
Khor Singari	**6.132**	**7.602**	**6.622**	**4.884**	**3.990**	**3.374**	**4.634**
Amada	**4.088**	**4.410**	**4.284**	**4.970**	**2.618**	**3.024**	**2.310**
Tushka	**3.220**	**3.654**	**9.898**	**2.338**	**2.100**	**2.352**	**2.604**
Khor Tushka	**2.380**	**4.690**	**2.772**	**3.374**	**3.556**	**3.570**	**2.282**
Abu Simbel	**5.432**	**3.038**	**2.632**	**3.360**	**2.884**	**3.108**	**1.708**
Khor Or	**0.812**	**2.044**	**1.792**	**1.372**	**1.288**	**0.882**	**0.700**
Adindan	**0.658**	**9.980**	**1.008**	**1.120**	**1.008**	**1.134**	**0.728**

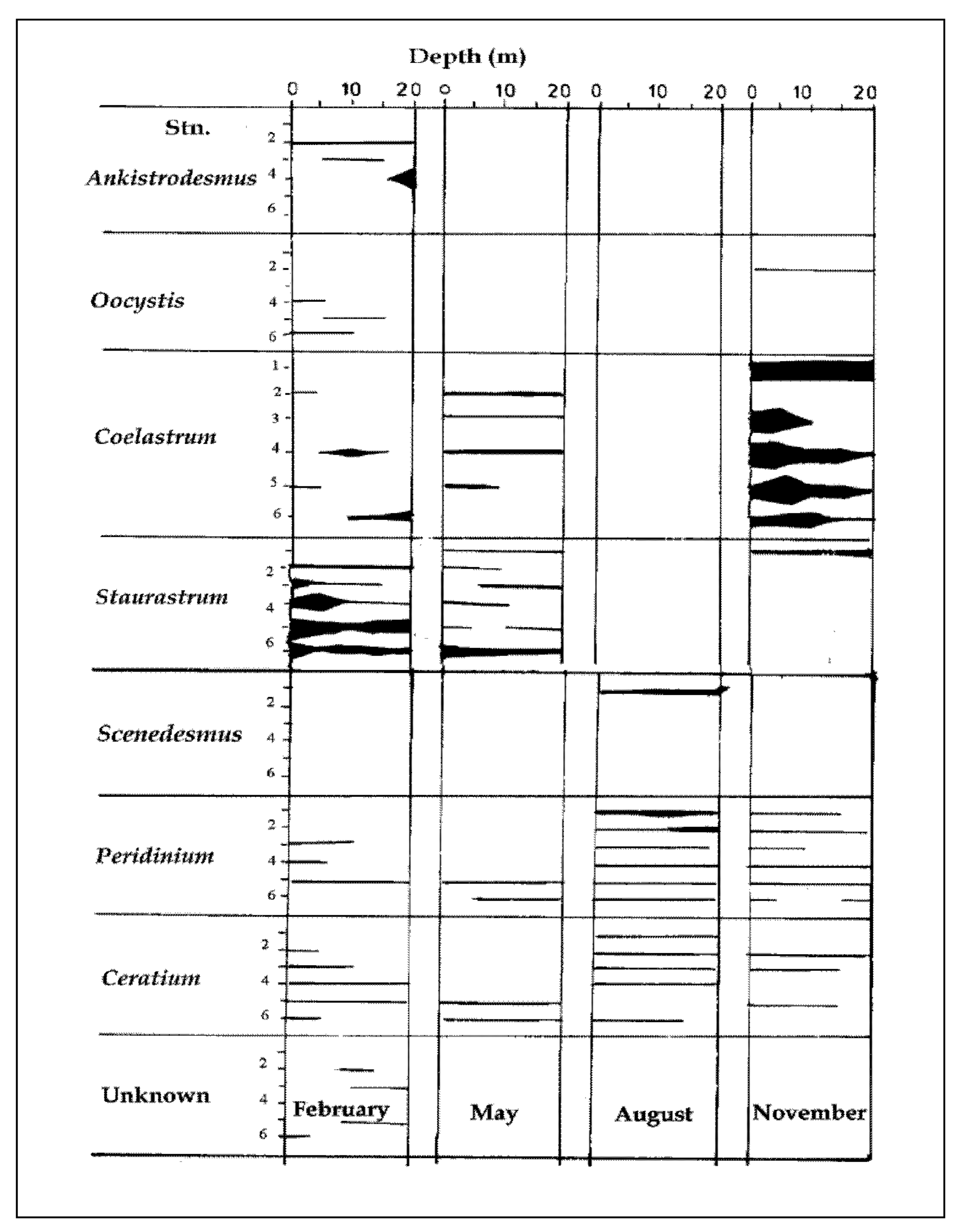


Fig. 70 **Seasonal changes of vertical distribution of phytoplankton in the main channel in 1990 (Mohamed, I. 1993j). Scale bar = 1000 cells/ml. [**For stations refer to Fig. 4**].**

Needless to mention that phytoplankton in Lake Nasser, at present, diatoms and cyanophytes (Cyanobacteria) preponderate along the main channel and even at all sites because both groups are well adapted to the new environmental conditions. All phytoplankton groups are responsible for

primary production, which is the basis of food webs in Lake Nasser. Therefore, the phytoplankton could intensively influence the economy of such a man-made Lake. Hence, the recorded planktonic algae are considered as the major source of food for the plankton feeding fishes, which are the dominant species in the Lake.

WATER BLOOMS

Sometimes serious problems of unbalanced biological conditions arise in sluggish areas of Lake Nasser. Overgrowth of Cyanophyceae species causes floating crusts and scums, where plants die quickly and disintegrate in the intense sunlight. This causes depletion of oxygen below the point required for fish and other aquatic animals. Mohamed, I. (1993k) recorded the occurrence of water blooms in Lake Nasser eight times during six years (from 1987 to 1992) and pointed out that water blooms occurred only in very limited areas of the southern part of the Lake. Cyanophyceae species were found in all samples of blooms. *Microcystis aeruginosa* was the dominant species in all the samples of water blooms (Mohamed, I. 1993k) (Table 46). The latter author pointed out that *Oscillatoria* spp. were observed in extreme values at Korosko, while *Aphanocapsa* sp. was present in high quantities at Abu Simbel.

Recently, water blooms have been recorded in the central area of the Lake. Occassionally they were seen at Korosko in the northern area. Formerly *M. aeruginosa* water blooms occurred annually for several months before the flood water period, but now they may occur intermittently all the year round (Mohamed, I. & Ioriya, 1998).

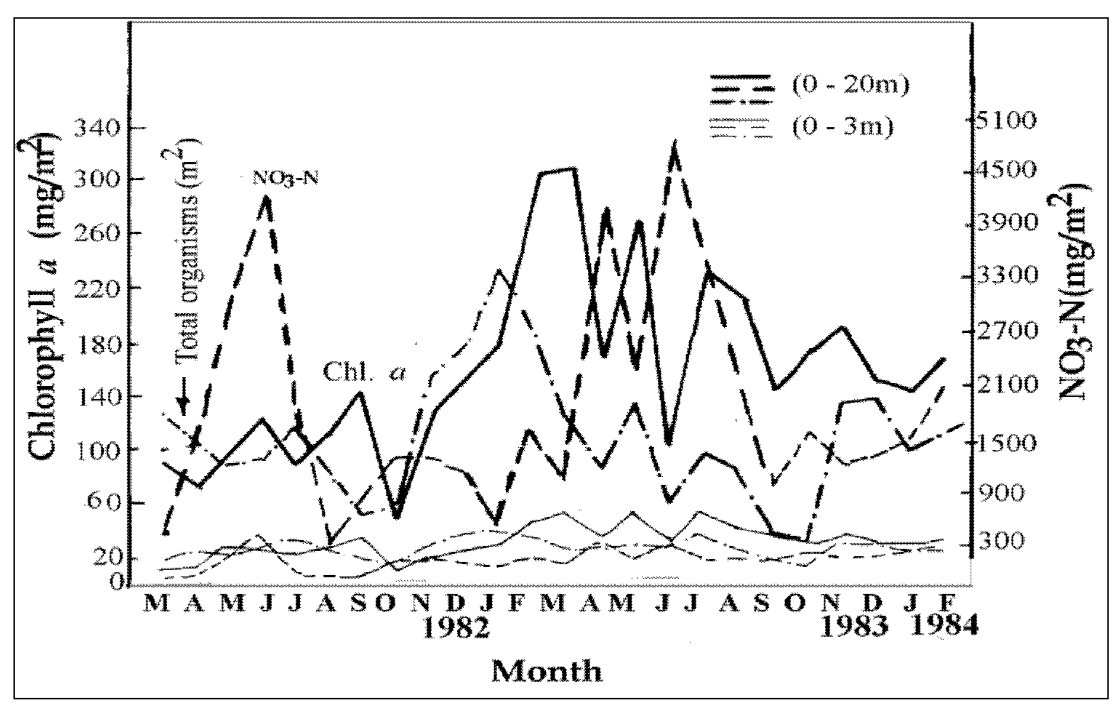


Fig. 71 **Depth-time distribution of NO_3-N ; chlorophyll *a* concentration and of total phytoplankton units under 1 m^2 down to a depth of 3 and 20 m in the Lake at site 1 (10 km south of AHD) [Mohamed *et al.* 1989].**

***Table** 45* **Temporal course of algal development and nitrate concentration by representation of higher, middle, and lower values from March 1982 to February 1984. (Belal *et al.* 1992).**

	1982										1983												1984	
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Total algal count	●	•	•	•	●	•	·	·	●	●	●	●	•	•	●	-	●	•	·	·	●	●	•	●
Chlorophyll *a*	•	•	·	•	·	•	•	·	•	●	●	●	●	●	●	·	●	●	•	●	●	•	•	●
O_2 (% Sat.)	●	●	•	·	•	·	·	•	·	•	●	●	●	●	●	·	•	·	·	●	●	●	●	●
pH	--	●	•	•	●	•	•	·	·	·	•	•	•	•	●	·	●	•	·	•	•	·	·	·
NO_3.N	•	•	●	●	•	·	·	•	•	•	·	•	·	●	•	●	●	•	·	•	•	•	•	•

● maximum, • moderate, · minimum values, -- not measured.

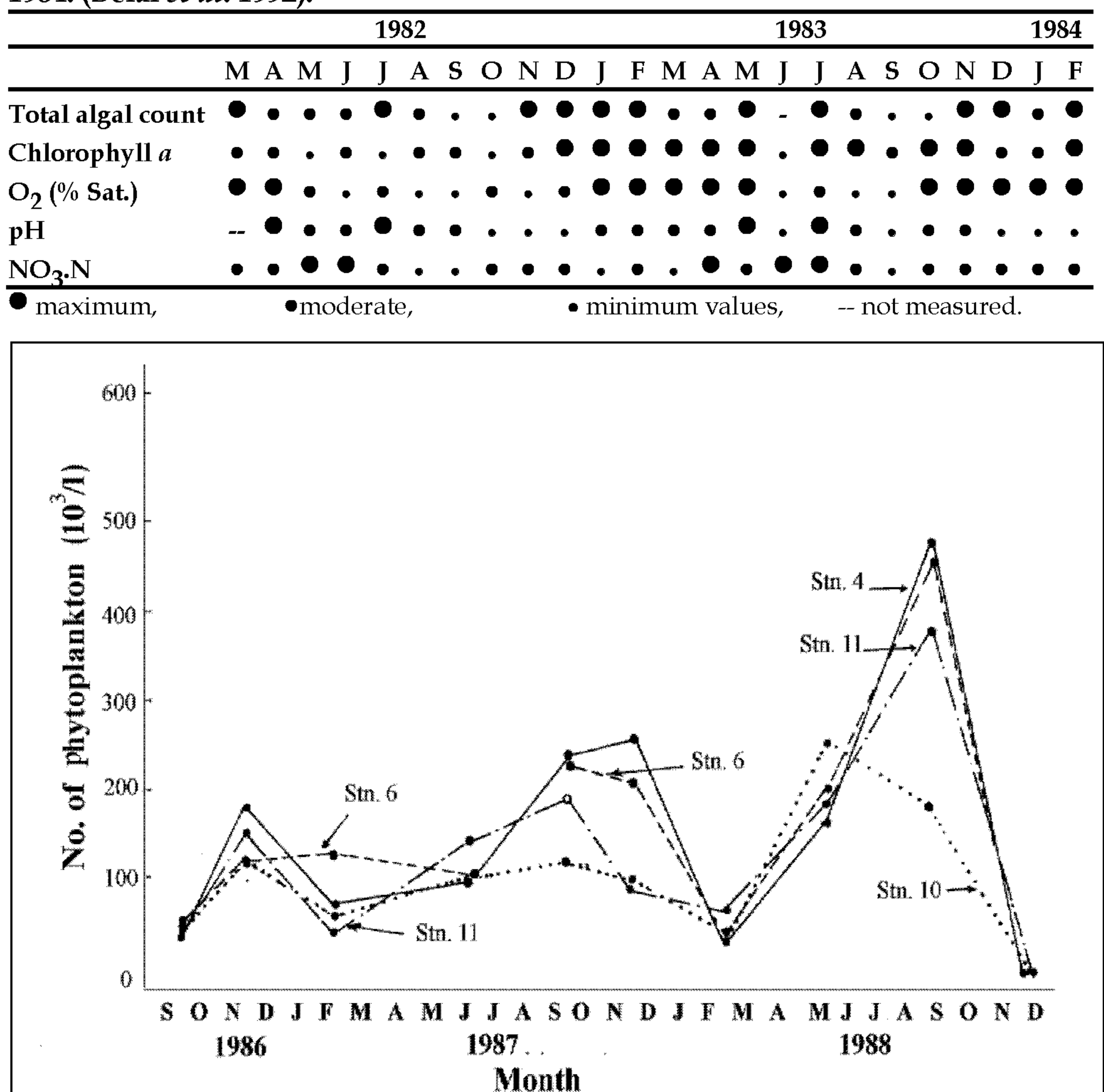


***Fig.** 72* **Seasonal variations of the total number of phytoplankton (algal units) at Khor El Ramla at four stations (Habib 1995c) [**For stations refer to Fig. 4**].**

CHLOROPHYLL *a*

The amount of chlorophyll *a* in water is an index of phytoplankton productivity and has been used to estimate the primary productivity in combination with data on photosynthetic activity on chlorophyll *a* basis and light conditions in freshwater lakes as well as in marine environments (Ichimura *et al.* 1962, Aruga & Monsi 1963). It will be possible to calculate primary productivity by phytoplankton in a lake on the basis of enough information on the photosynthetic and respiratory activities of phytoplankton and the diurnal and seasonal changes of light conditions.

Table 46 **Cell number of water blooms in Lake Nasser (Mohamed, I. 1993k) unit: cell/10 ml.**

Date	Site	Genera								
		Micr.	*Nost.*	*Anab.*	*Osci.*	*Phor.*	*Melo.*	*Apha.*	*Cycl.*	Phot. Bac.
Aug. 19, 1987	**Tushka**	4710	462	54	--	--	--	--	--	372
Aug. 19, 1987	**Abu Simbel**	5760	480	315	--	--	--	--	--	462
Aug. 16, 1988	**Korosko**	1322	129	--	196	--	---	--	--	654
Sep. 9 , 1989	**Tushka**	2601	96	--	3957	105	--	--	--	261
Dec. 11, 1989	**El Seboui**	2337	--	--	--	324	156	--	--	--
Aug. 14, 1991	**Abu Simbel**	5661	216	165	129	54	--	--	--	309
Oct. 16, 1992	**Abu Simbel**	1017	--	--	215	--	189	109	9	--
Oct. 16, 1992	**Wadi El Arab**	2799	--	--	410	--	111	1110	24	--

Micr. : ***Microcystis aeruginosa***   *Nost.* : ***Nostoc*** **sp.**
Anab : ***Anabaena*** **sp.**   *Osci.* : ***Oscillatoria*** **sp.**
Phor. : ***Phormidium*** **sp.**   *Apha.* : ***Aphanocapsa*** **sp.**
Cycl. : ***Cyclotella*** **sp.**   *Melo.* : ***Melosira*** **spp.**
Phot. Bact. : **Photosynthetic bacteria**

Many investigators studied the seasonal, horizontal, vertical and regional concentrations of chlorophyll *a* along the main channel of Lake Nasser as well as in some of the khors since the early stages of Lake Nasser filling (Fead 1980; Habib 1984, 1992a and b, 1996a, 1997; Habib *et al.* 1987; Mohamed, I. 1993a-c and 1996a and b; Abdel-Monem 1995). The results indicate that chlorophyll *a* concentration in the upper 8 m layer is high at the southern region compared with that at the northern region of the Lake. High chlorophyll *a* concentrations are recorded in the upper 8 m layer from March or April to October or November.

Usually, a stratified vertical distribution of chlorophyll *a* was observed in April-September, and a homogeneous vertical distribution in November-February. In the stratified distribution the subsurface chlorophyll *a* maximum was found at 2 m depth. The highest chlorophyll *a* concentration (42.4 mg/m^3) was recorded at the surface layer in January 1984 at stn. 4 (Koroska) (Habib & Aruga, 1996), while the lowest concentration (0.0 mg/m^3) was recorded at stns. 1 (El Ramla) and 3 (Allaqi) at 30 m depth in July and September 1992 (Mohamed, I. 1996b).

It seems that chlorophyll *a* shows seasonal changes with high values during the high temperature period and low values during the low temperature period. Furthermore, Secchi disk depth from 0.3 to 5.5 m, being high during low temperature period and low chlorophyll *a* concentration; and low during high temperature period and high chlorophyll *a* concentration. A summary of the results of some investigators is shown in Tables 47, 48, and 50 -52.

The relationship between chlorophyll *a* concentration and Secchi disk depth obtained by various investigators in Lake Nasser and its khors (Habib 1996a, Habib *et al.* 1992 & 1996; Mohamed, I. 1993a-c, 1995a & b, 1996a & b)

seems to be similar to those reported in other freshwater lakes (Ichimura 1961) and in marine waters (Ichimura & Saijo 1959, Saijo & Ichimura 1960, Shibata & Aruga 1982, Brandini & Aruga 1983).

I. The Main Channel

(a) Regional variations. The southern region of Lake Nasser (stations 4, 5 and 6 - Fig. 4) showed higher mean annual values of chlorophyll *a* concentration (about 12 mg/m^3) than the northern region (stations 1, 2 and 3) (about 8-11 mg/m^3). Fead (1980) recorded the highest concentration of chlorophyll *a* at Abu Simbel directly preceding the annual flood. This may be partly due to the supply of sufficient nutrient salts from upper stream of the Nile to the southern part of the Lake and to the flood waters which push ahead multitudes of phytoplankton to the southern part of Lake Nasser, thus resulting in the highest figures of chlorophyll *a* recorded through the year. Mohamed, I. (1992a, 1993a, 1995b and 1996b) studied the regional variation of chlorophyll *a* concentration along the main channel and its relation with the temperature and his results are shown in Table 47 and Figs. 73-75.

(b) Seasonal variations. No distinct seasonal variations of chlorophyll *a* concentration were observed in the northern stations (1-3), while stations 4-6 in the southern region of the Lake showed distinct seasonal variations. The highest chlorophyll *a* concentrations were recorded during summer and spring, while low chlorophyll *a* concentrations were found in autumn and winter (Table 48). The highest seasonal variations of chlorophyll *a* were recorded at the southern three stations, less at the northern three stations. Levels of chlorophyll *a* concentrations were generally high during the period of high water temperature (Table 47 and Figs. 73 - 75).

The seasonal changes of the average chlorophyll *a* concentration in the upper 8 m layer are illustrated in Fig. 76 (Habib & Aruga 1996). The results of the latter authors indicate that the levels of chlorophyll *a* concentration were generally high (1.0-24.0 mg/m^3) at stns. 4-6 at the southern region, and low (1.0-16.5 mg/m^3) at stns. 1-3 in the northern region of the Lake. The patterns of seasonal changes of chlorophyll *a* were similar among stns. 1-3 and among stns. 4-6, but the patterns at the latter stations were clearly different from those at the former stations (Fig. 76 C and D). The range of chlorophyll *a* variations was quite high at stns. 4-6 as compared with stns. 1-3. A rapid increase in chlorophyll *a* concentration was observed in July or August at stns. 4-6 in 1984, and stns. 4 and 5 in 1985 (Fig. 76-D). The same trends were also observed in spring-early summer at stns. 1-3 in 1984 and 1985, even though the increase was much less (Fig. 76-C). Chlorophyll *a* concentration was high during the period of high water temperature and low during the period of low water temperature at stns. 4-6 in 1984 and 1985.

Table 47 **Seasonal, vertical and regional variations of chlorophyll *a* concentration (mg/m^3) along the main channel of Lake Nasser.**

		Year of Investigation and Author						
		1982-83 Habib (1992a)	**1983-84 Habib (1992b)**	**1986-87 Mohamed I. (1993a)**	**1988 Mohamed I. (1993b)**	**1989 Mohamed I. (1993c)**	**1990 Mohamed I. (1995b)**	**1992 Mohamed,I. (1996b)**
Maximum	**Value**	27-24	26.8	28.2	27.2	26	22	17.2
Conc.	**Stn.**	4	5	3	6	5	6	5
	Depth (m)	0-10	--	--	10	30	10	0
	Date	Sept. 82	Aug. 84	Nov. 86	Jan.	Jan.	Aug.	Aug.
Minimum	**Value**	1.2	3.0	2.8	0.5	0.1	0.1	0.0
Conc.	**Stn.**	4,5,6	1	5	6	4	6	1.3
	Depth (m)	0-10	--	--	30	30	30	30
	Date	Nov. Dec. 82	Jan. 84	Feb. 87	Feb.	Aug.	July, Aug.	July, Sept.
Temp. (°C)	**From**	15.0	16.5	16.6	16.2	14.9	-	15.2
	Stn.	1	6	6	6	6	-	6
	Depth(m)	4	20	--	30	4	-	30
	Date	Feb. 83	Feb. 84	Jan. 87	Jan.	Feb.	-	--
	To	29.7	31.5	31.7	31.9	32.4	-	31.3
	Stn.	5	2	4	6	5	-	2
	Depth (m)	0.0	0	--	0	0	-	0
	Date	Sep. 83	July 84	Aug. 87	Aug.	Aug.	-	--
Transpare-ncy	**From**	-	-	0.3	0.4	0.4	0.6	0.3
	Stn.	-	-	6	6	6	6	6
(range m)	**Date**	-	-	Aug. 87	Sept.	Sept.	Sept.	Aug.
	To	-	-	5.8	5.3	5.4	6.1	5.8
	Stn.	-	-	1	1	1	6	1
	Date	-	-	Dec.	Dec.	March	Dec.	March)

For stations refer to Fig. 4. Stn. 1 (El Ramla), Stn. 2 (Kalabsha), Stn. 3 (Allaqi), Stn. 4 (Korosko), Stn. 5 (Tushka), Stn. 6 (Abu Simbel).

Figure 77 illustrates the seasonal changes of chlorophyll *a* concentration in the surface water and 2 m layer at stns. 1-6 along the main channel of Lake Nasser from September 1986 to December 1988 (Habib *et al.* 1996). The results show that the averages of chlorophyll *a* concentrations were slightly higher at stns. 4-6 (1-26 mg/m^3) than at stns. 1-3 (1-21 mg/m^3). The seasonal patterns of chlorophyll *a* concentration were similar among stns. 1-3 and among stns. 4-6, even though the patterns at stns. 1 and 6 were rather obscure as compared with those of other stations. The patterns at stns. 1-3 were different from those at stns. 4-6. The range of seasonal variations of chlorophyll *a* concentration was high at stns. 4-6 as compared with that at stns. 1-3.

Table 48 **Seasonal average of chlorophyll *a* concentration (mg/m^3) at various stations in the main channel from October 1983 to August 1984 (Habib 1992a).**

Season	**1**	**2**	**3**	**4**	**5**	**6**
Autumn	7.9	6.8	9.7	19.1	15.2	14.4
Winter	5.1	8.5	13.0	7.0	7.2	9.1
Spring	7.1	11.0	10.0	10.3	8.3	10.0
Summer	10.2	10.3	11.7	14.6	17.4	15.3

[For stations refer to Fig. 4].

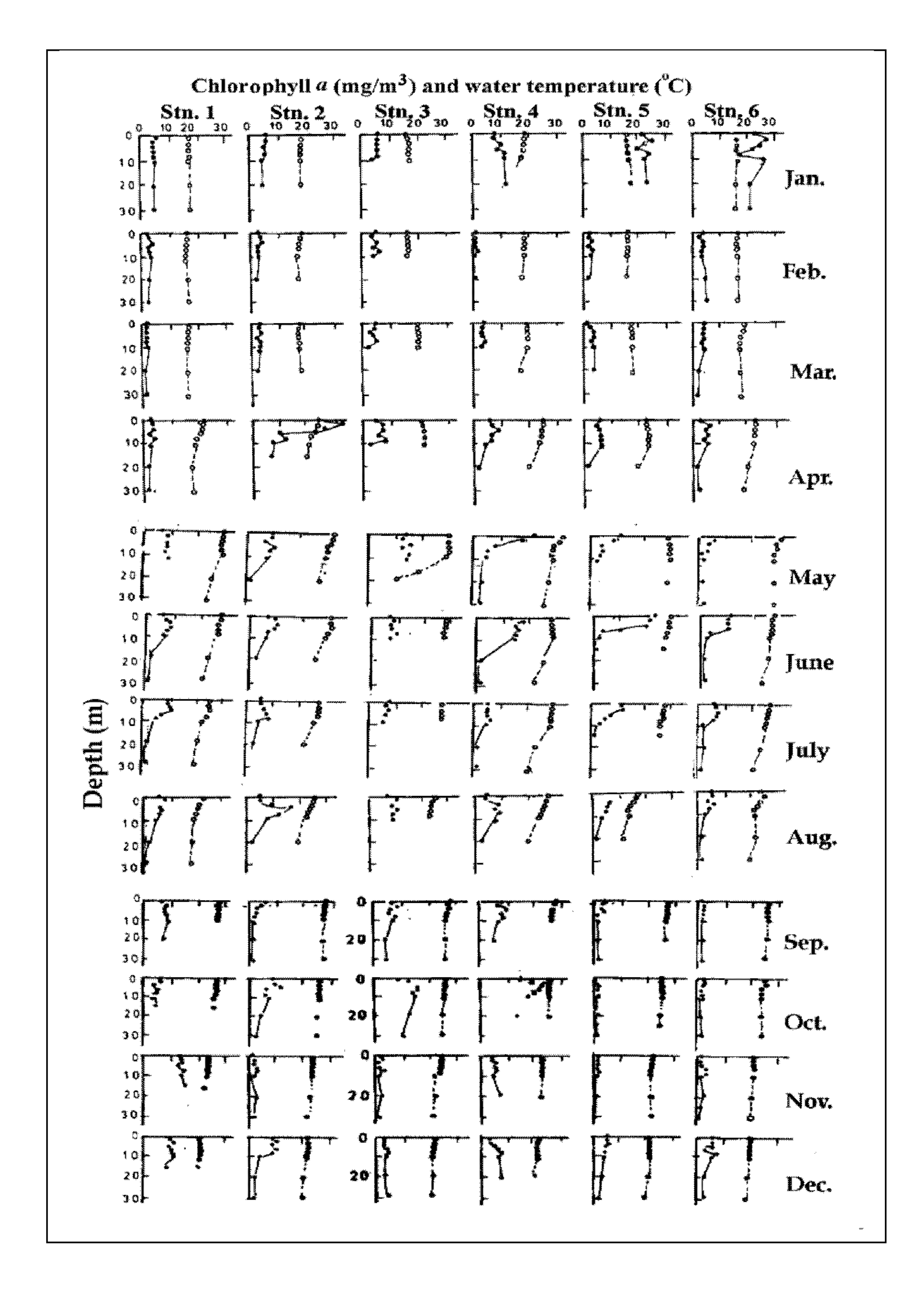
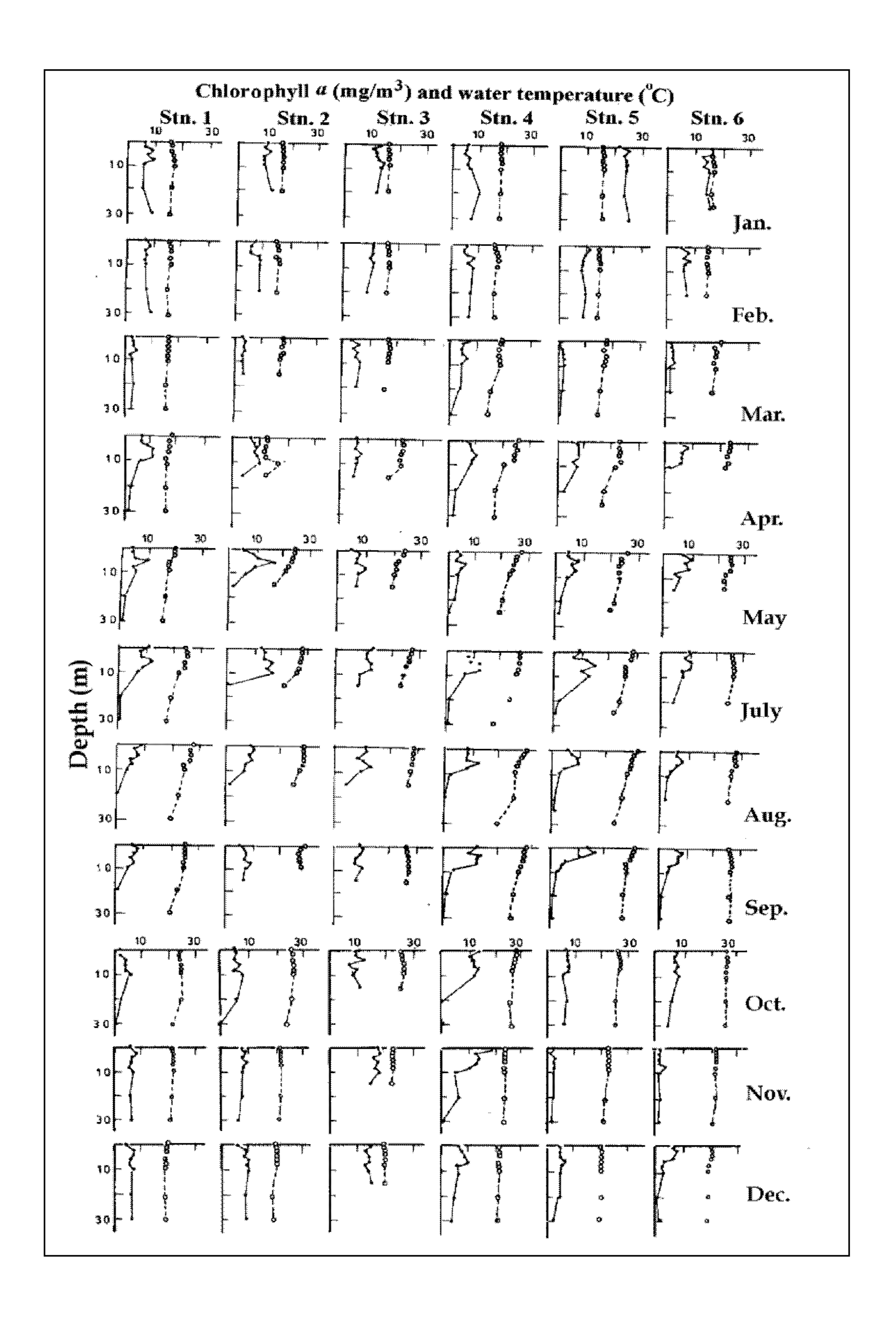


Fig. 73 **Vertical distribution of chlorophyll *a* concentration (•—•) and water temperature (o......o) in the main channel of Lake Nasser during 1988 (Mohamed, I. 1993e). [**For stations refer to Fig. 4**].**



Chlorophyll a (mg/m3) and water temperature (°C)
Stn. 1
Stn. 2
Stn. 3
Stn. 4
Stn. 5
Stn. 6
Depth (m)
Jan.
Feb.
Mar.
Apr.
May
July
Aug.
Sep.
Oct.
Nov.
Dec.

Fig. 74 **Vertical distribution of chlorophyll *a* concentration (•—•) and water temperature (o.......o) in the main channel during 1989 (Mohamed, I. 1993 g) [**For stations refer to Fig. 4**].**

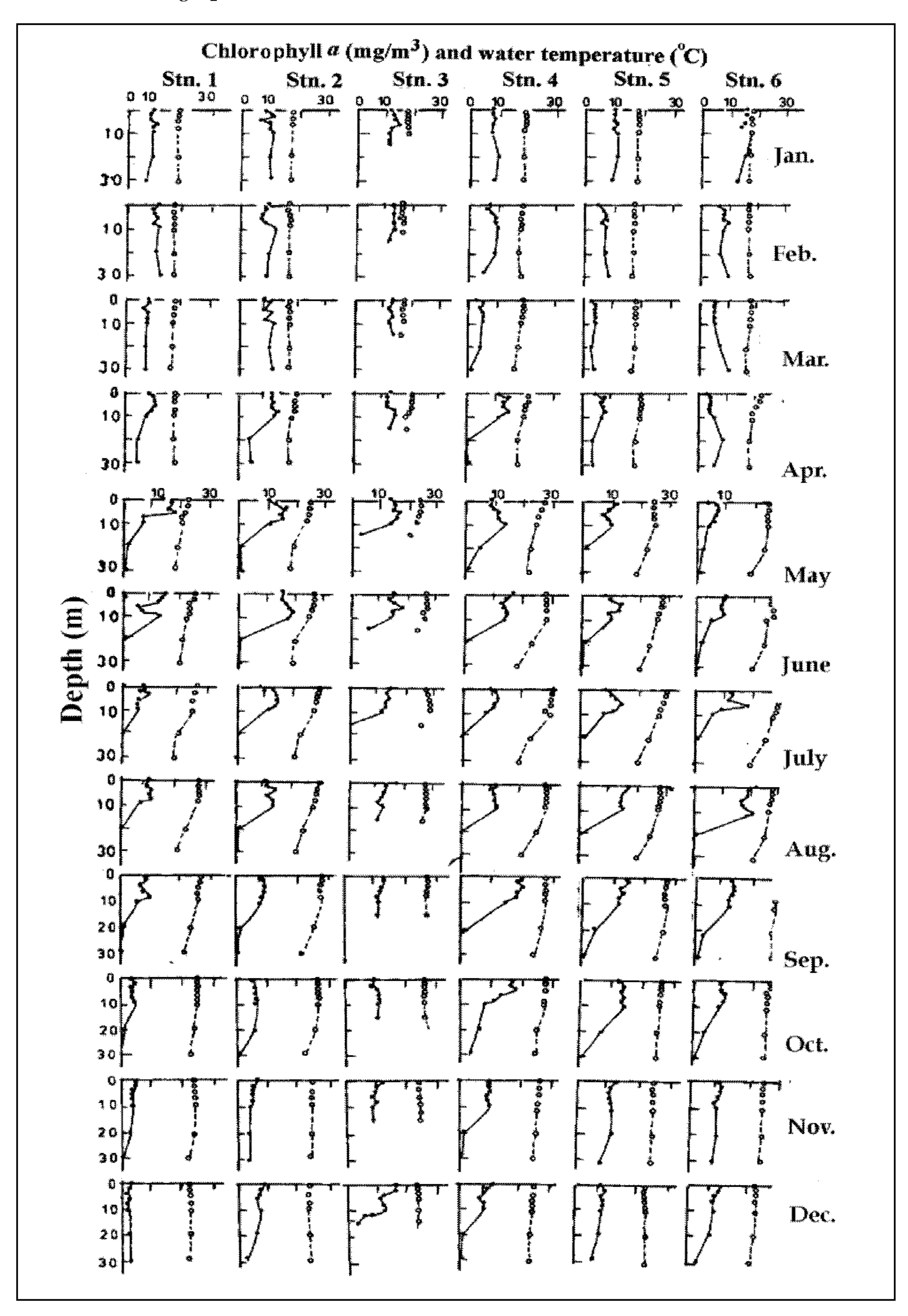


Fig. 75 **Monthly variations of chlorophyll *a* concentration (mg/m^3) and water temperature (°C) at six stations in the main channel during 1990 (Mohamed, I. 1995b). (Temperature: (o.......o) chlorophyll *a :* •—•) [**For stations refer to Fig. 4**].**

(c) Vertical variations. High and homogenous values of chlorophyll *a* concentrations were recorded in the upper layers of the water column till 8 m depth. The highest values were recorded at 2 and 4 m depth because the photosynthetic activities of phytoplankton at the surface were inhibited by high light intensity of solar radiation. Thus, the highest production was obtained at about 2 m depth and gradually decreased with depth (Latif, 1974b); low values in deep layers up to 30 m were due to the depletion of light. This supports the previous conclusion of Fead (1980) that the concentration of chlorophyll *a* in Lake Nasser correlates with the depth of the euphotic zone suggesting that chlorophyll *a* is the main variable controlling light penetration into the non-flood waters of the reservoir.

In their study in October 1982 through December 1985, Habib *et al.* (1996) showed that the upper layer of the water column from the surface to a depth of 8 m showed high chlorophyll *a* concentrations; deeper layers usually contain less chlorophyll *a*. However, similar high chlorophyll *a* concentrations as in the upper layer were recorded in deeper layers at several stations in some months. Usually the homogenous type of vertical distribution was found in November through February coinciding with the low water temperature, while the stratified type in April through September coinciding with a clear thermocline which was observed during March to October (Ichimura 1961). The subsurface maxima of chlorophyll *a* were obtained mostly at depths 2-6 m during the period April-July. The observed maximum concentration of chlorophyll *a* was 57.6 mg/m^3 at 2 m in November 1984 at stn. 1.

The vertical distribution of chlorophyll *a* concentration along the main channel of the Lake during 1988 was studied by Mohamed, I. (1993e - Fig. 73 and Table 47). The highest concentration (27.2 mg/m^3) was recorded at 10 m depth of stn. 6 in January, and a high value (26.7 mg/m^3) was found at 30 m depth at stn. 6 in February. Mohamed, I. (1993g) recorded the highest concentration of chlorophyll *a* (26.0 mg/m^3) at stn. 5 at 30 m depth in January 1989, while the lowest concentration (0.1 mg/m^3) was recorded at stn. 4 at 30 m depth in August 1989 (Fig. 74 and Table 47). In 1996 (SECSF) the maximum value of chlorophyll *a* concentration in the main channel (23.95 mg/m^3) was recorded in summer at surface waters at Abu Simbel, and the minimum value (1.06 mg/m^3) was found at Kalabsha at 6 m depth. During winter there was an increase of chlorophyll *a* concentration in deeper water (5-7 m) as compared with surface water. At Kalabsha and Allaqi high concentrations were recorded compared with other localities during the same season.

Relationship between chlorophyll *a* concentration and Secchi disk depths. The relationships between chlorophyll *a* concentration and Secchi disk depth in the surface water and 2 m-layer at stns. 1-6 in the main channel of Lake Nasser during the period from October 1983 to December 1985 are shown in

Fig. 78 (Habib & Aruga 1996). Data are greatly scattered possibly due to

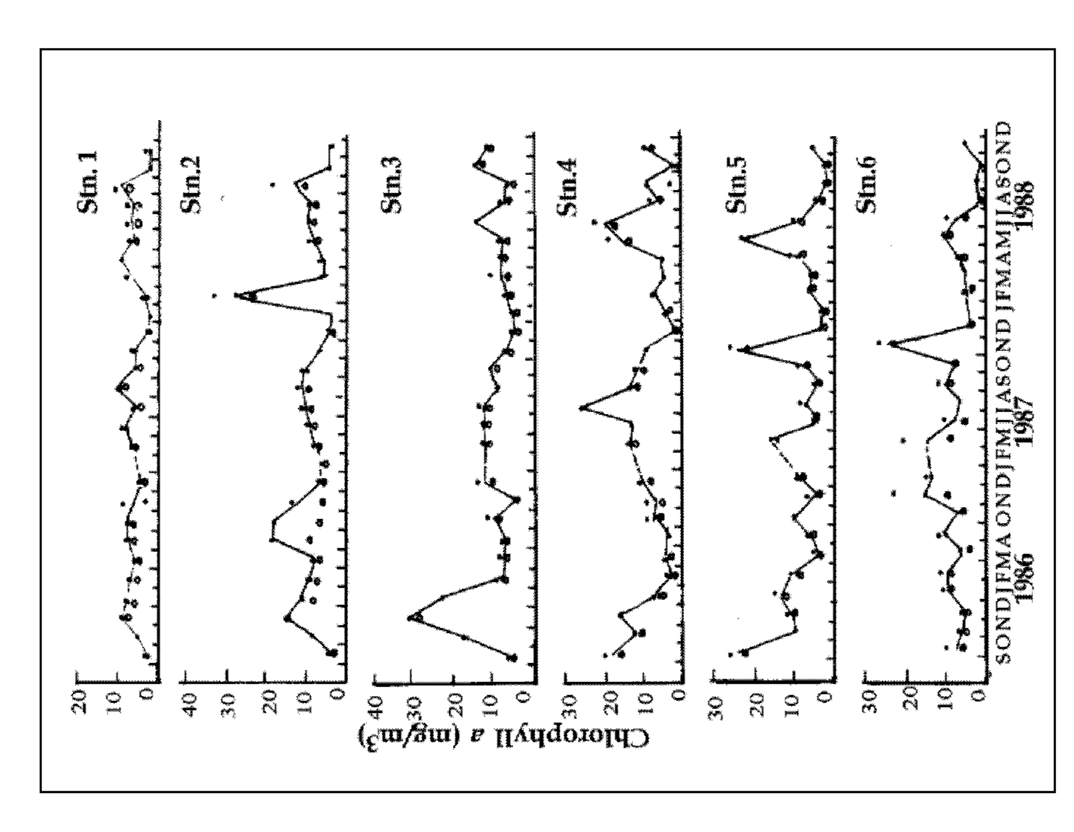


Fig. 77 **Seasonal changes of chlorophyll *a* at stns. 1-6 in the main channel of Lake Nasser (Habib *et al.* 1996). Lines are for average of the surface (◦) and 2 m (·) samples** [For stations refer to Fig. 4].

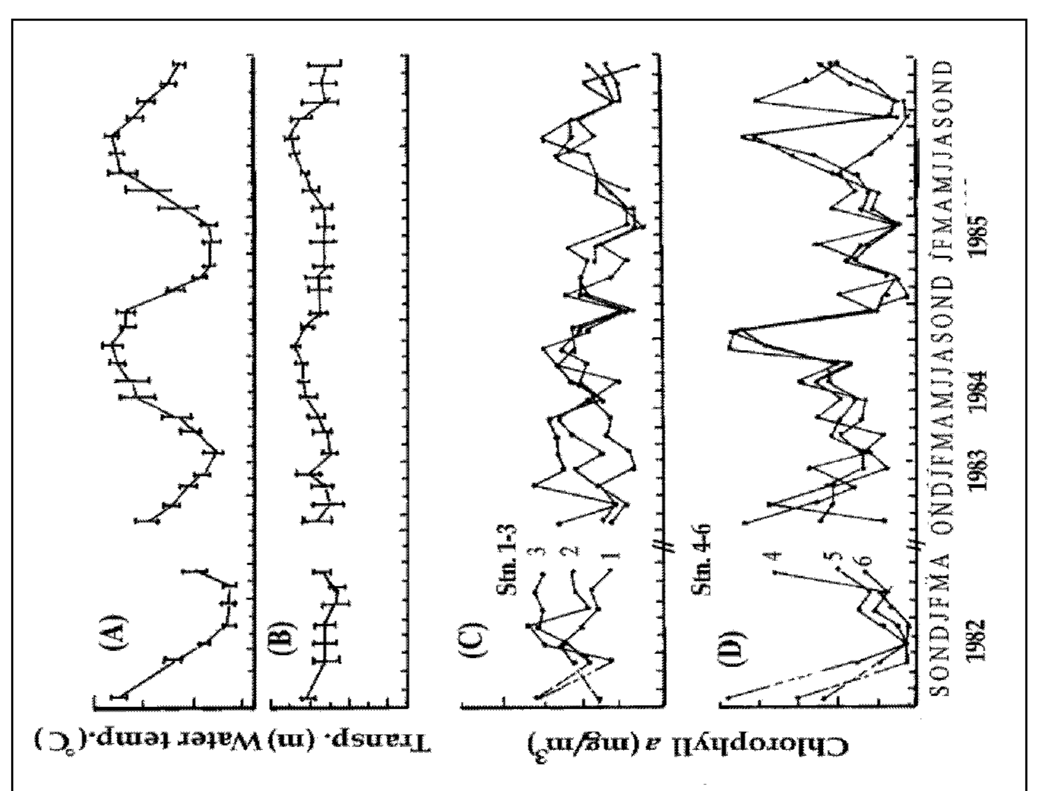


Fig 76 **Seasonal changes of A: average water temperature in the upper 8 m layer, B: transparency, and C and D : average chlorophyll *a* concentrations in the upper 8m layer at stns. 1-6 in the main channel of the Lake Nasser. Vertical bars in A and B indicate the standard deviation (Habib & Aruga 1996).**

greater variability of the proportion of inorganic solids in suspended matter in the Lake water. If the upper levels of chlorophyll *a* concentration at respective Secchi disk depth are taken into consideration by assuming relative contribution of inorganic suspended solids to attenuation of light in water, the relationship seems to be exponential on a semilogarithmic plot as reported by several investigators (Ichimura 1956, Ichimura & Saijo 1959 and Ichimura 1960, Schibata & Aruga 1982, Brandini & Aruga 1983, Habib *et al*. 1987) in various waters.

Relationship between chlorophyll *a* concentration and suspended solids. The relationship between chlorophyll *a* concentration and suspended solids was studied for the surface water and the 2-m layer at stns. 1-6 along the main channel of Lake Nasser (Fig. 79 - Habib *et al*. 1996). The results indicate positive correlation between the two parameters. However, the data points were very much scattered. There is no significant difference between the relationships in the two layers.

Relationship between chlorophyll *a* concentration and particulate organic matter. The relationship between chlorophyll *a* concentration and particulate organic matter for the surface water and 2-m layer was studied at stns. 1-6 along the main channel of Lake Nasser (Fig. 80 - Habib *et al*. 1996). The results show that there were positive correlations with considerable scattered data points between the two parameters and no significant difference was observed between the two layers.

II. The Khors

Lake Nasser has side branches known as khors. There are 85 khors; 48 of which lie on the eastern side and 37 on the western side. Some of these khors are deep, narrow and with rocky bottom as Singari and Korosko. On the other hand, other khor bottoms are relatively wide with sandy or sandy loam as Kalabsha, Tushka and El Ramla. Some of these khors are very rich in the fish production.

1. In Khor El Ramla. Khor El Ramla (Fig. 81) is situated at the western side of Lake Nasser, about 10 km south of High Dam with relatively wide sandy or sandy loam bottom. Morphology of the khor at 180 m above mean sea level (MSL) was provided by Entz (1974a) and summarized in Table 49. Thorough study of chlorophyll *a* was carried out in this khor (Habib 1992b) and the results are summarized as follows:

(a) Regional variation. Generally, the concentrations of chlorophyll *a* inside Khor El Ramla and at its entrance were higher than those outside the khor (i.e. in the main channel and eastern part of the Lake). The mean values of chlorophyll *a* concentration were about 10.8 mg/m^3 inside the khor, 9.0 mg/m^3 at the entrance of the khor and 7.8 mg/m^3 outside the khor, i.e. in the main channel (Table 50).

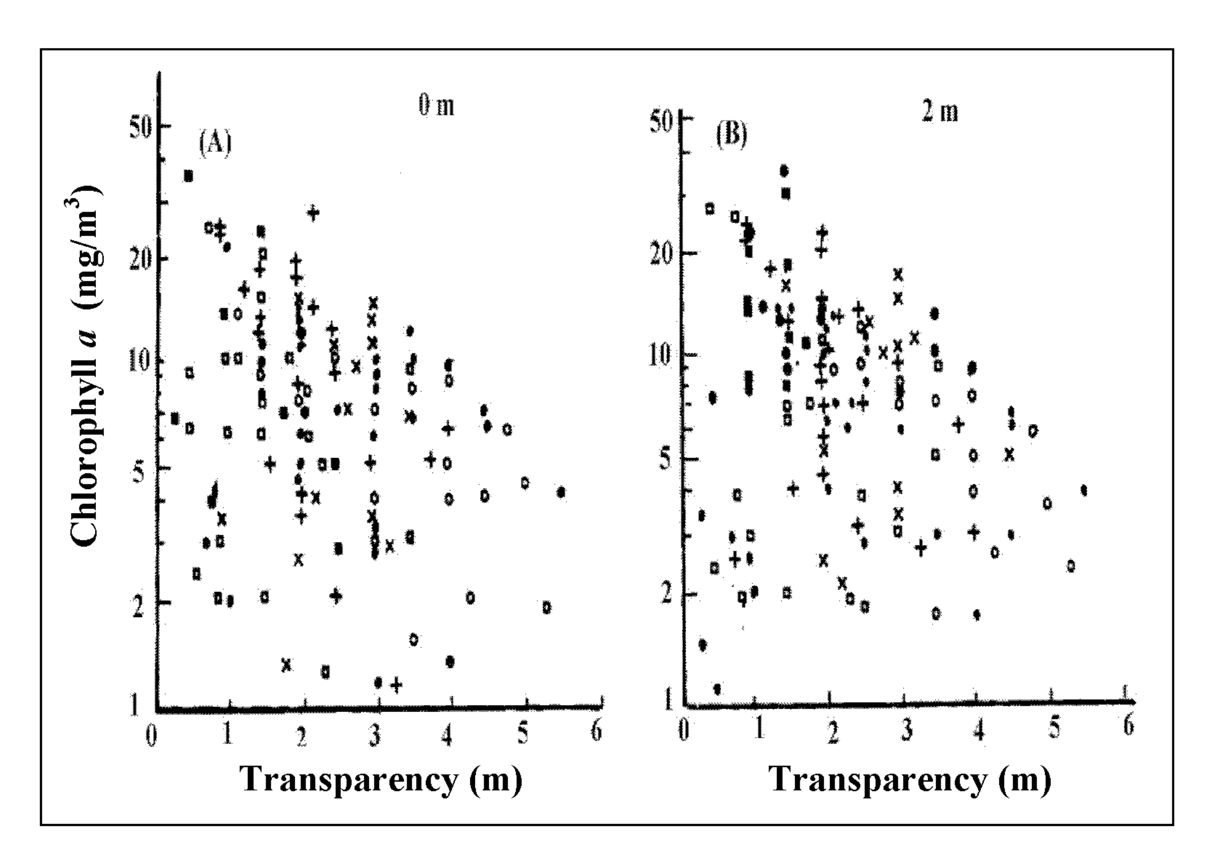


Fig. 78 **Relationships between the transparency and chlorophyll *a* concentration in the surface water (A) and the 2m layer (B) at stns. 1-6 in the main channel of Lake Nasser. Data from October to December 1985. (○) Stn.1, (•) Stn. 2, (x) Stn. 3, (+) Stn. 4, (□) Stn. 5, (▪) Stn. 6 (Habib & Aruga 1996)** [For stations refer to Fig. 4].

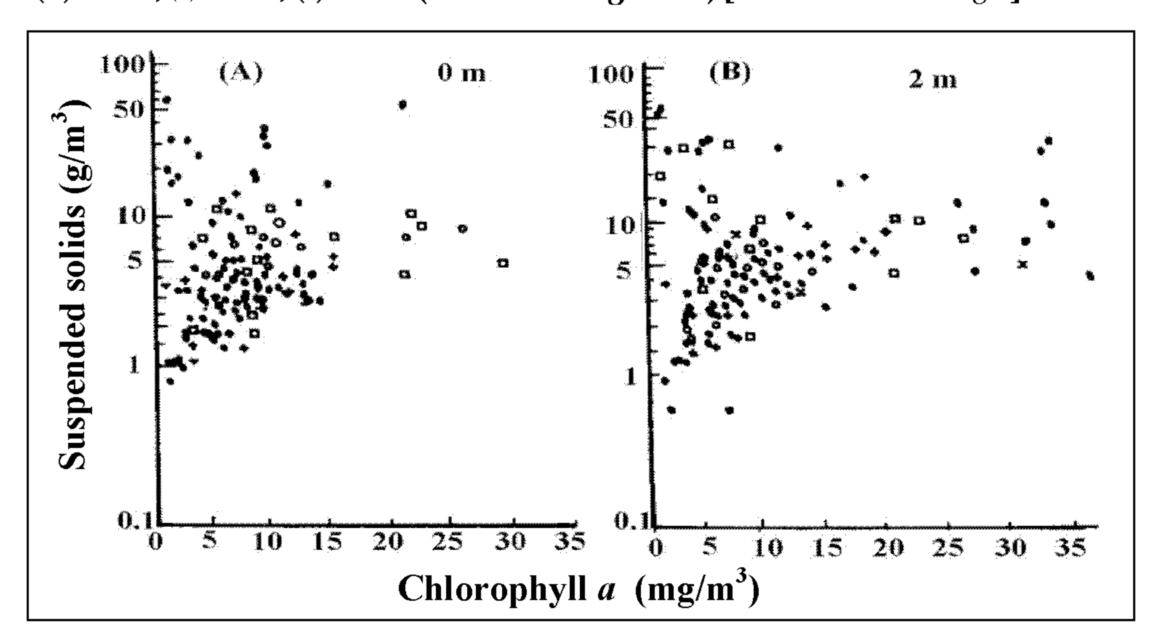


Fig. 79 **Relationships between the suspended solids and chlorophyll *a* at stns. 1-6 in the main channel of Lake Nasser. (○) Stn.1, (•) Stn. 2, (x) Stn. 3, (+) Stn. 4, (□) Stn. 5, (▪) Stn. 6 (Habib *et al.* 1996)** [For stations refer to Fig. 4].

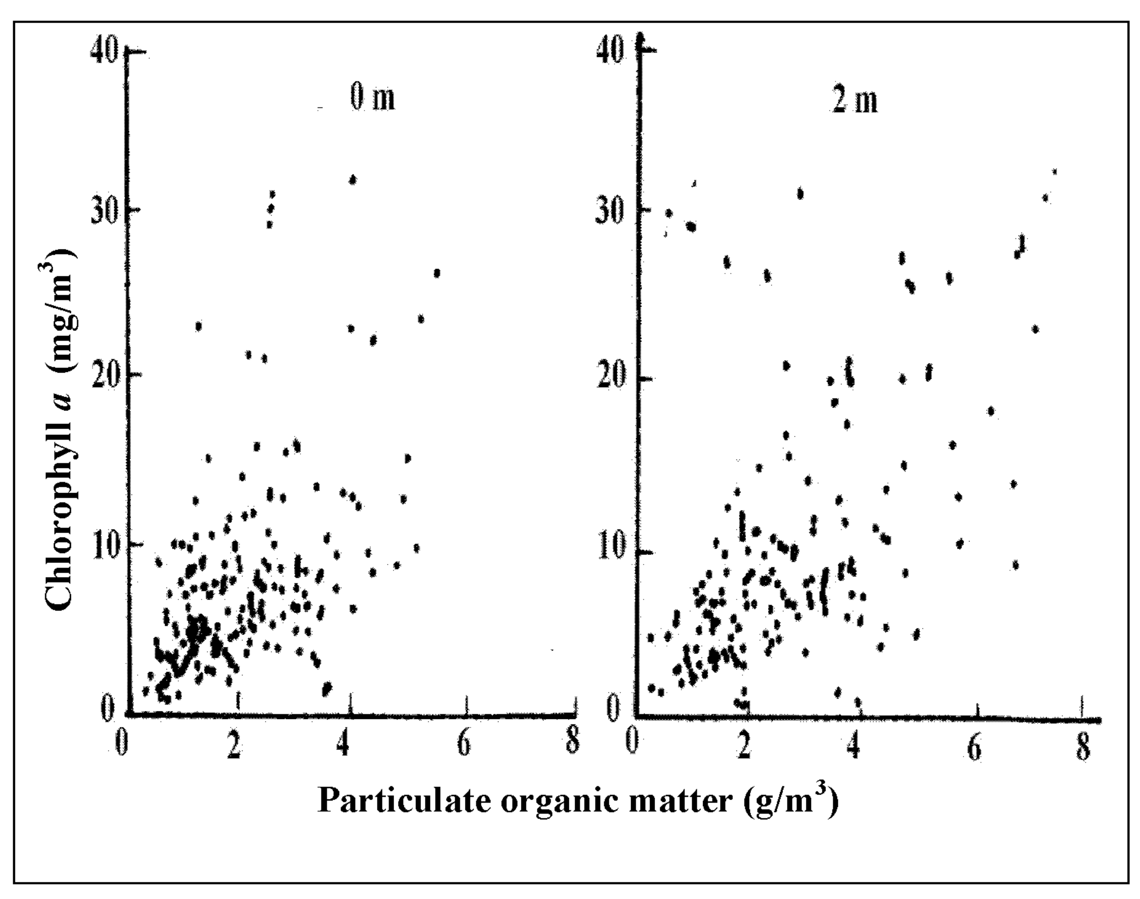


Fig.80 **Relationship between chlorophyll *a* concentration and the particulate organic matter at stns. 1-6 in the main channel (Habib *et al.* 1996).**

(b) Seasonal variation. Generally, chlorophyll *a* concentrations were high in spring (March and April), decreased in autumn (October and November) and in winter (December, January and February) in a descending order. In autumn and spring chlorophyll *a* concentration inside the khor showed the highest values compared with those at the entrance and outside the khor but in winter chlorophyll *a* concentration at the entrance of the khor showed the highest values (Table 50).

Table 49 **Morphometery of Khors El Ramla and Kalabsha at 180m above MSL (Entz 1974a).**

		Khor El Ramla	Khor Kalabsha
Distance from HD	(km)	10.00	44.00
Shoreline	(km)	232.00	464.00
Length	(km)	23.6	47.20
Mean width	(km)	1.2	--
Mean depth	(m)	21.00	9.88
Surface area	(km^2)	95.2	620.00
Volume	(km^3)	2.15	7.16

Table 50 **The mean value of chlorophyll *a* concentration (mg/m^3) in and outside Khor El Ramla and at its entrance (Habib 1992b).**

Month	Inside the khor Stns. (1-4)	At the entrance of the khor-Stns. (5-7)	Outside the khor Stns. (8-13)
Oct. 1982	11.1	5.8	4.7
Nov.	11.6	11.5	7.7
Dec.	11.9	9.7	5.8
Jan. 1983	6.7	11.7	10.5
Feb.	7.2	7.6	8.1
Mar.	10.6	7.6	9.6
April	16.4	9.0	8.5
Mean	10.8	9.0	7.8

For stations refer to Fig. 81.

Chlorophyll *a* concentration and water temperature at 4 stations in Khor El Ramla for the surface water layer from September 1986 to December 1988 are shown in Fig. 82 (Habib 1995a). The results indicate that maximum chlorophyll *a* concentration (i.e. 32.1 mg/m^3) was recorded in March 1987 at stn. 4, while the minimum value (i.e. 2.0 mg/m^3) was in December 1988. Generally, spring and summer showed high chlorophyll *a* concentrations, while low concentrations were recorded in winter.

Habib *et al.* (1996) investigated the distribution of chlorophyll *a* at 13 stations inside and outside Khor El Ramla (Fig. 81) from October 1982 through December 1985. The seasonal changes of the average chlorophyll *a* concentration in the upper layer of 0-8 m at stns. 1-13 are illustrated in Fig. 83. It is obvious that the levels of chlorophyll *a* concentration were generally higher at stns. 1-3 in the khor than at other stations in the main channel. The range of variations of chlorophyll *a* concentration was also higher at stns. 1-3 (1-46 mg/m^3) in the khor than at other stations (1-20 mg/m^3) in the main channel. Trends of seasonal changes at stns. 1-3 (Fig. 83 A) in the khor were different from those at other stations (Fig. 83 B-D) outside the khor, although the changes at stn. 4 were rather similar to those at stn. 3. Trends of the change were rather similar at stns. 5-13 (Fig. 83 B-D) even though the detailed variations were different from one another. A rapid increase of chlorophyll *a* concentration was observed in March, April and May at stns. 1 and 3 in the khor to attain the highest levels especially at stns. 1 and 2. An exceptionally high value of chlorophyll *a* (106.8 mg/m^3 at 4 m depth) was recorded in April 1984 at stn. 2. The levels of chlorophyll *a* were very high during the low temperature in November 1984 - February 1985 at stns. 1-3 (Fig. 83 A). At stations outside the khor, the levels of chlorophyll *a* concentrations were generally higher during

the period of high water temperature and low during the period of low water temperature (Fig. 83 B-D). Chlorophyll *a* concentrations distinctly decreased in November and December 1985 at stns 4, 6, 10 and 11 (Fig. 83 C).

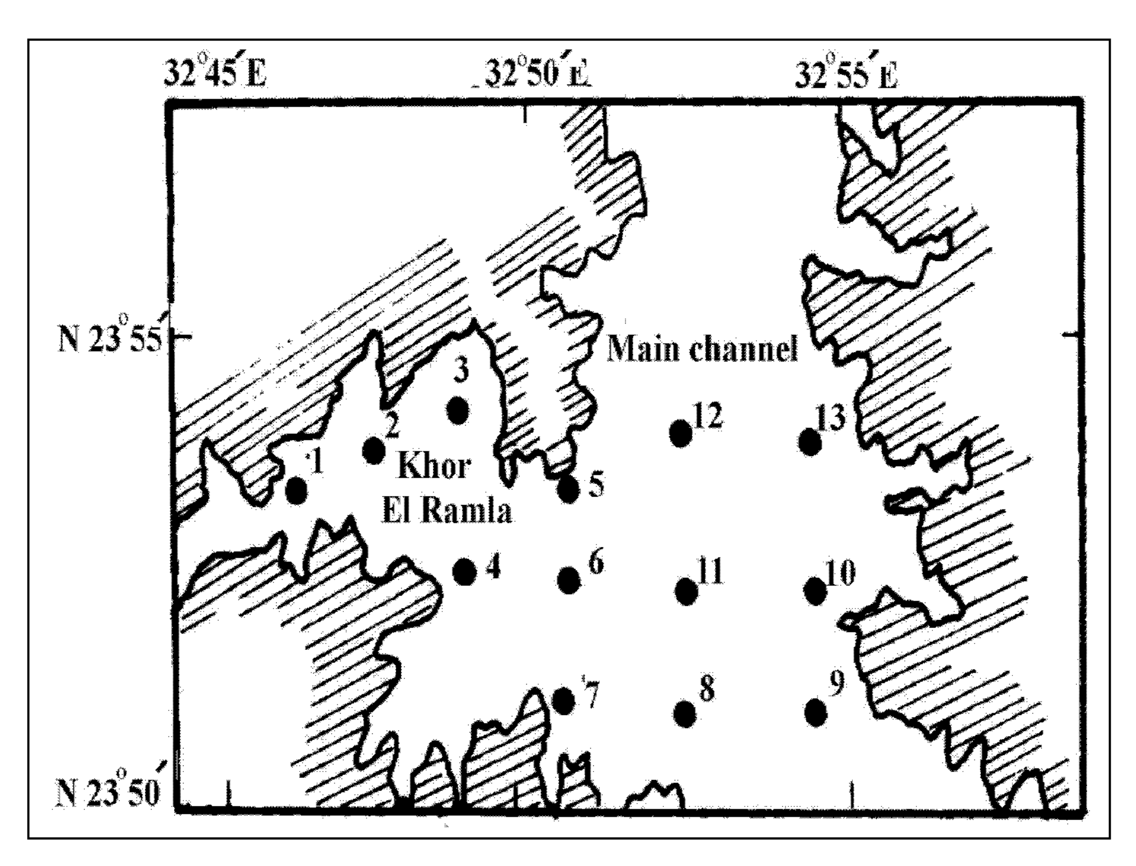


Fig. 81 **Location map of Lake Nasser and Khor El Ramla showing sampling stations. Figures indicate station numbers (Habib 1992b).**

(c) Vertical distribution. Generally, there were no wide variations in the vertical distribution of chlorophyll *a* inside, at the entrance and outside Khor El Ramla during any month except in March and April 1983 when there were wide variations of chlorophyll *a* distribution along the water column, e.g. 14 mg/m^3 at stn. 1 in March, 39 mg/m^3 at stn. 1 in April, and 18 mg/m^3 at stn. 2 in April (Table 51 - Habib 1992b).

Habib *et al.* (1996) studied the vertical distribution of chlorophyll *a* concentration at 13 stations inside and outside Khor El Ramla (Fig. 81) from October 1982 through December 1985. The results show that chlorophyll *a* concentration was usually high in the upper layer from the surface to 8 m depth. The subsurface chlorophyll *a* maxima were obtained mostly at 2-6 m depth during April to August, while in other months the surface maxima or the homogenous type of distribution was observed. The patterns of vertical distribution at stations inside the khor were generally different from those at stations outside the khor. The observed subsurface maxima of

chlorophyll *a* may be related to the photoinhibition of phytoplankton

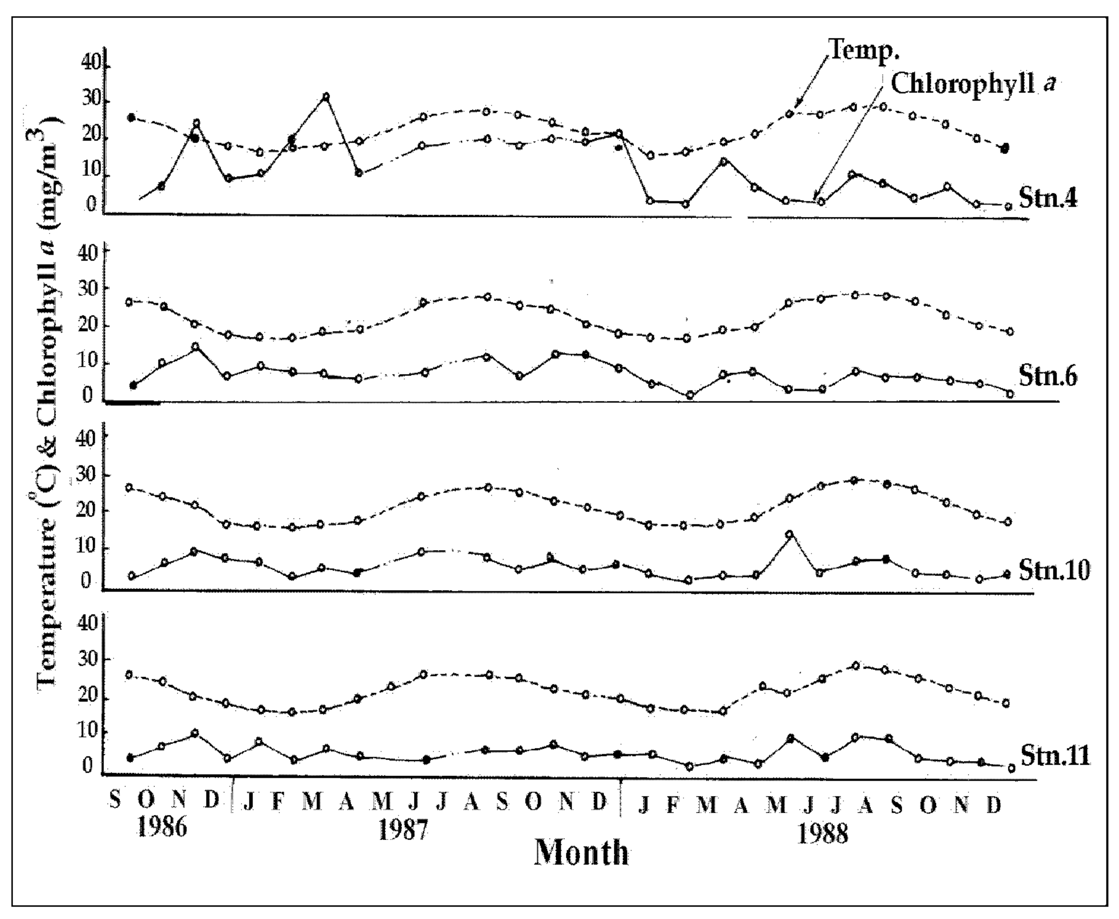


Fig. 82 **Seasonal variations of chlorophyll *a* (○——○) and water temperature (○- - -○) at 4 stations in Khor El Ramla (Habib 1995a) [**For stations refer to Fig. 81**].**

Table 51 **The vertical variation of chlorophyll *a* concentration (mg/m^3) in and outside Khor El Ramla (Habib 1992b).**

Month	Inside the khor Stns. (1-4)	At the entrance of the khor-Stns. (5-7)	Outside the khor Stns. (8-13)
Oct., 1982	3-6	1-3	1-3
Nov.	2-5	1-6	1-3
Dec.	2-6	1-4	1-2
Jan., 1983	1-3	1	1
Feb.	1-6	1-2	1-2
Mar.	4-14	5-7	2-6

April	4-39	3-6	2-7

For stations refer to Fig. 81.

photosynthesis at the surface layer due to high solar radiation (Latif 1974b). According to Raymont (1980), it is common in tropical marine waters to find out a maximum of algal growth near the base of the euphotic zone with generally abundant light and also with high nutrient concentrations. Low values in deeper layers down to 30 m might be due to the depletion of light.

(d) Variation in different years. The highest concentration of chlorophyll *a* inside Khor El Ramla was 57.6 mg/m^3 recorded in November 1984 at Stn. 1 (Habib *et al.* 1996). Yearly variations of chlorophyll *a* were recorded during different years as follows (Table 52):

1986/1987: The highest concentration of chlorophyll *a* (24.0 mg/m^3) was recorded at stn. 4 in November 1986, and high values of 20.5, 20.1 and 19.9 mg/m^3 were recorded at the same station in February, June and March 1987 respectively. The lowest value for chlorophyll *a* concentration (3.1 mg/m^3) was recorded at stn. 10 in March 1986 and stn. 11 in February 1987 (Table 52). The high value of Secchi disk extinction depth showed low chlorophyll *a* concentrations during winter, and the low value of Secchi disk extinction depth was paralleled by high chlorophyll *a* concentration.

1988: The highest value of chlorophyll *a* recorded was 26.2 mg/m^3 at stn. 4 inside Khor El Ramla at 4 m depth in April, and the lowest value was 0.8 mg/m^3 at stn. 11 outside Khor El Ramla at a depth of 30 m in September (Table 52). Transparency was high at areas where chlorophyll *a* concentration was low and vice versa.

1989: The maximum concentration of chlorophyll *a* (20.5 mg/m^3) was recorded at stn. 4 inside Khor El Ramla at 8 m-depth in December, and the minimum concentration of 0.2 mg/m^3 was recorded at stn. 11 outside Khor El Ramla at 30 m-depth in August. A correlation was observed between transparency and chlorophyll *a* concentration. When the value of transparency was high, chlorophyll *a* concentration was also low (Table 52, Mohamed, I. 1993f).

1990: The maximum value of chlorophyll *a* concentration (29.2 mg/m^3) was recorded at stn. 4 (4 m depth) in June, and the minimum value (0.1 mg/m^3) was recorded at stn. 11 (30 m-depth) in June. The transparency was usually low

during the period of high chlorophyll *a* concentration and high during the period of low chlorophyll *a* concentration.

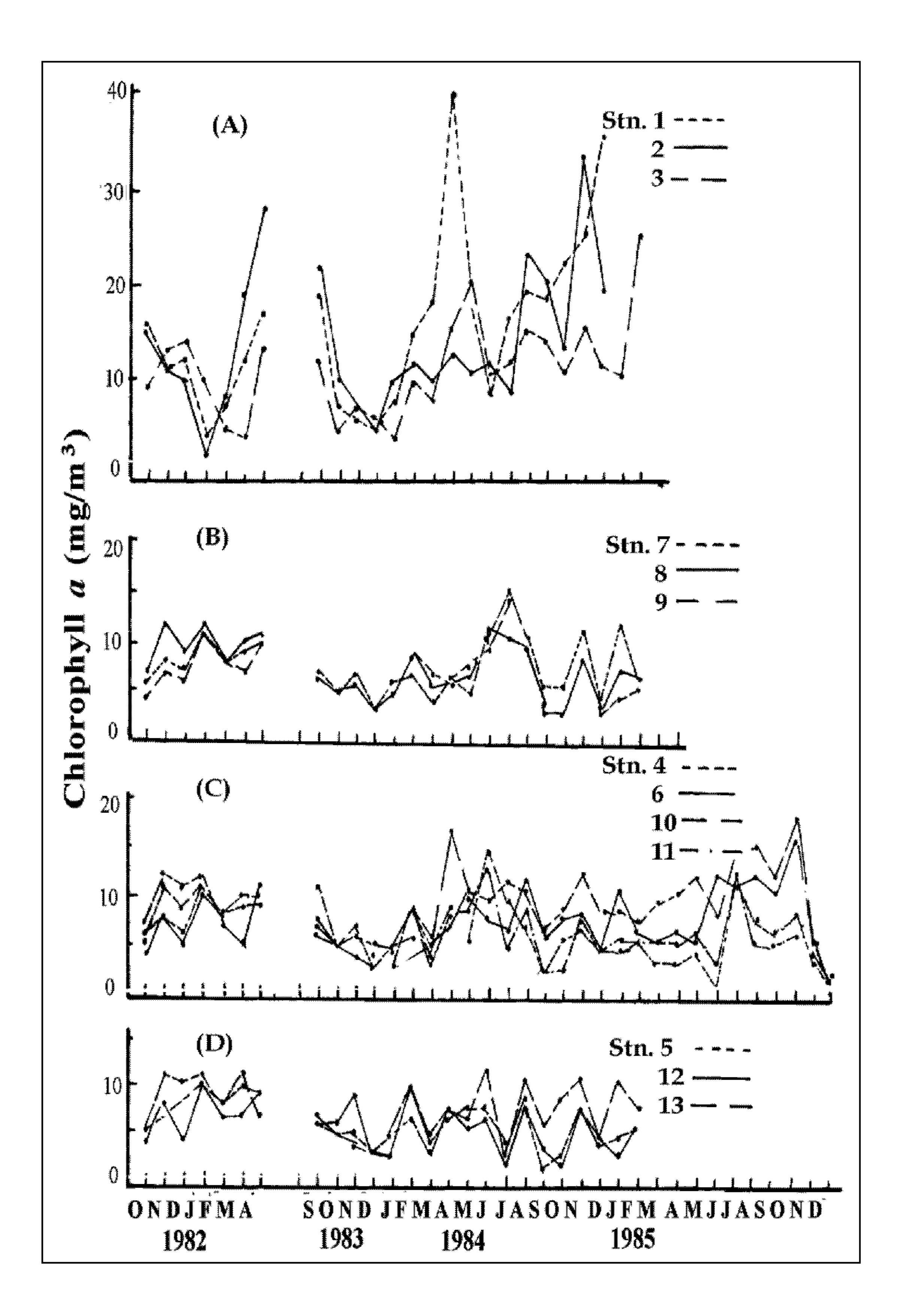


Fig. 83 **Seasonal changes of the average chlorophyll *a* concentration from the surface to 8 m depth at 13 stations in Khor El Ramla and in the main channel (Habib *et al.* 1996)** [For stations refer to Fig. 81].

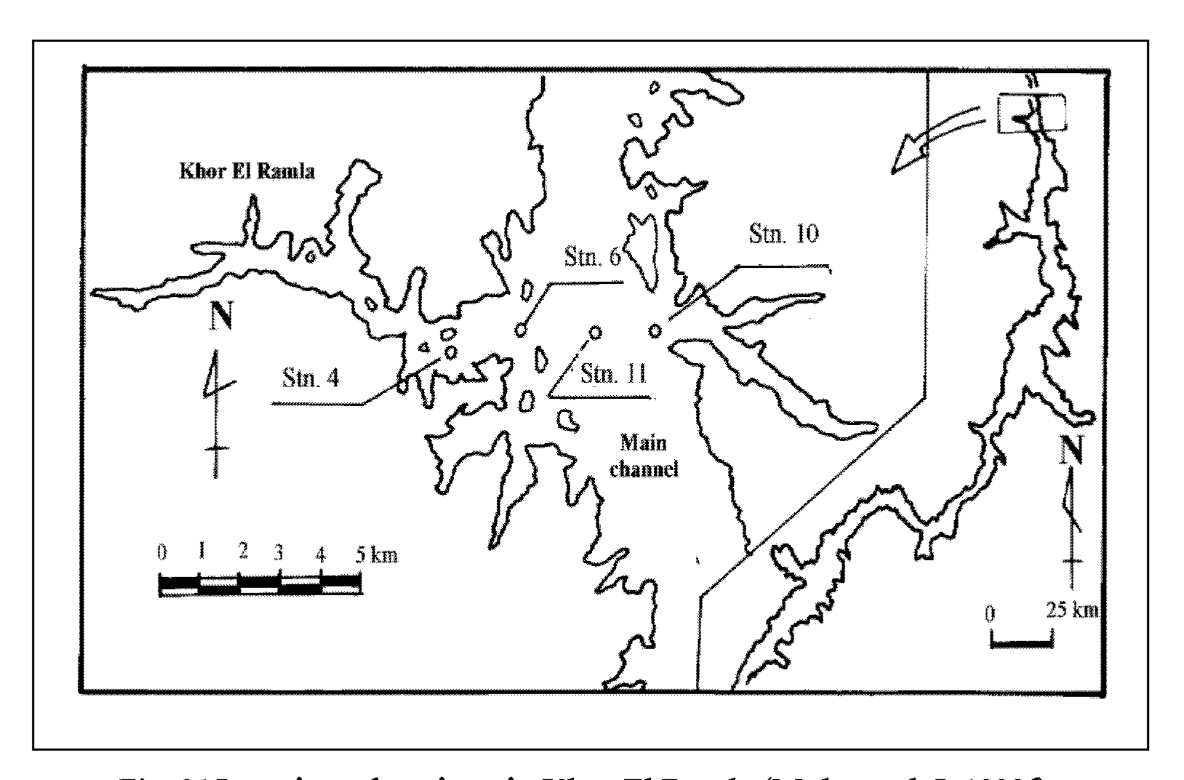


Fig. 84 **Location of stations in Khor El Ramla (Mohamed, I. 1993f).**

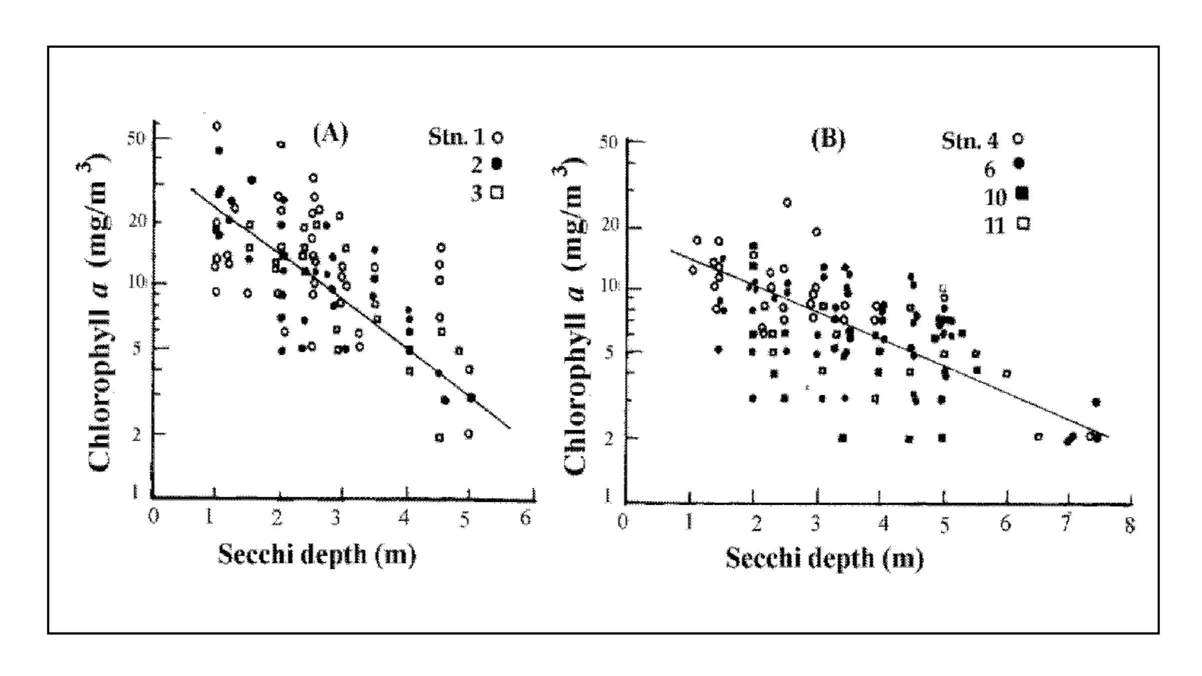


Fig. 85 **Relationships between the Secchi disk depth and chlorophyll *a* concentrations in the surface water and at 2 m depth for stns. 1-3 (A) and stns. 4, 6, 10 and 11 at Khor El Ramla (B) (Habib *et al.* 1996) [**For stations refer to Fig. 81**].**

At station 4 in Khor El Ramla the highest values of chlorophyll *a* are recorded during 1986 to 1990, while minimum values were found at stations 10 and 11 in the main channel.

Relationships between chlorophyll *a* concentration and the Secchi disk depths. Habib *et al.* (1996) studied the relationships of chlorophyll *a* concentration to the Secchi disk depth inside Khor El Ramla (stns. 1-3, Fig. 85). Both relationships are exponential when plotted on a semilogarithmic diagram, or hyperbolic when plotted on a normal diagram in a similar manner as reported in freshwater lakes (Ichimura 1956) and in marine waters (Ichimura & Saijo 1959, Saijo & Ichimura 1960, Schibata & Aruga 1982, Brandini & Aruga 1983). The relationships (Fig. 85) are almost similar, but the gradient of the regression line is slightly different from one to another. This difference might have been dependent on the different composition of suspended matter in the water of the khor and in the main channel (outside the khor), suspended matter should have contained more particles other than living phytoplankton in the main channel than in the khor.

Table 52 **Variation of chlorophyll *a* concentration (mg/m^3) in Khor El Ramla during 1986-1990 (Mohamed, I. 1993 b, f and 1996a).**

		Year of Investigation and Author			
		1986/87 Mohamed, I. (1993b)	**1988 Mohamed, I. (1993f)**	**1989 Mohamed, I. (1993h)**	**1990 Mohamed, I. (1996a)**
Maximum	**Value**	24.0	26.2	20.2	29.2
Conc.	**Stn.**	4	4	4	4
	Depth (m)	within euphotic zone	4	8	4
	Date	Nov. 86	April.	Dec.	June
Minimum	**Value**	3.1	0.8	0.2	0.1
Conc.	**Stn.**	10, 11	11	11	11
	Depth (m)	within euphotic zone	30	30	30
	Date	March 86 & Feb.87	Sept.	Aug.	June
Temp. (°C)	**From**	16	17.1	15.5	16.8
	Stn.	4	6	6	4
	Depth (m)	within euphotic zone	30	10	15
	Date	June 86	Feb.	Feb.	May
	To	28.9	30.2	29.0	30.2
	Stn.	10	10	6	10
	Depth (m)	within euphotic zone	---	0.0	0.0
	Date	July, 86	July	July	June
Transparency	**From**	1.2	1.3	1.2	1.1
(range, m)	**Stn.**	6	10	10	10

Date	Aug. 87	July	July	May
To	6.0	7.3	6.4	5.3
Stn.	4	11	4 & 6	10
Date	Feb. 86	Nov.	Feb.	May

[For stations refer to Fig. 84].

2. Khor Kalabsha. Khor Kalabsha (Fig. 86) is located in the northern part of Lake Nasser, about 44 km south of the High Dam. It covers an area of about 620 km^2 and its length is about 47.2 km (Table 49). Mohamed, I. (1993c) studied the regional and seasonal variations of chlorophyll *a* concentration in Khor Kalabsha; his results are given below:

Regional variation. The highest values of chlorophyll *a* were recorded at the central part of the khor (stns. 3 and 4) in May 1986 (Tables 53 and 54). Lower values of chlorophyll *a* were observed at stns. 8 and 9, i.e. at the entrance of the khor. The lowest value (2.6 mg/m^3) was recorded at station 9 in August 1986 (Tables 53 and 54).

Generally, in both khors (El Ramla and Kalabsha) the concentrations of chlorophyll *a* are higher inside the khors than outside. Therefore, khors of Lake Nasser are more productive than the main channel. Moreover, southern khors are more productive than the northern. Thus, in Khor Kalabsha (44 km south of the H D) the highest concentration of chlorophyll *a* was recorded (32 mg/m^3) compared with only 24.5 mg/m^3 at Khor El Ramla (10 km south of the HD) (Table 54).

***Table* 53 Average chlorophyll *a* concentration (mg/m^3) at the euphotic zone at 9 stations in Khor Kalabsha in 1986/1987 (Mohamed, I. 1993c).**

Month and Date	Stations								
	1	2	3	4	5	6	7	8	9
May 6-8, 86	16.6	9.7	31.5	32.1	26.7	4.4	5.8	16.9	13.9
Aug. 7-8, 86	7.5	4.4	8.3	8.2	7.3	7.0	--	5.0	2.6
Nov. 20-22, 86	8.4	14.5	25.0	21.1	25.3	18.1	8.5	22.2	17.2
Dec. 28-30, 86	14.9	26.2	17.1	16.1	20.5	16.6	15.3	13.8	10.5
June 29-30, 87	---	---	12.2	15.1	4.8	---	--	6.0	5.4

[For stations refer to Fig. 86].

Chlorophyll *a* for Net and Nanoplankton

Abdel-Monem (1995) studied chlorophyll *a* of net and nanoplankton and his results show that the nanoplankton (<20 μm) constituted the major component of chlorophyll *a* in the main channel of Lake Nasser in 1993 with few exceptions where net plankton (>20 μm) was dominant (Table 55). The highest average values for net and nanoplankton chlorophyll *a* were recorded

in spring and the lowest in winter. The seasonal variations of chlorophyll *a* were as follows:

Winter: Chlorophyll *a* concentrations were higher at the northern region than at the southern. Nanoplankton chlorophyll *a* constituted the major component of total chlorophyll *a* at all sites except at the bottom waters of Adindan. The highest value of chlorophyll *a* for net and nanoplankton (8.3 μg/l) was recorded at El-Madiq at 3 m depth, while the minimum value was found at Adindan at 15 m depth.

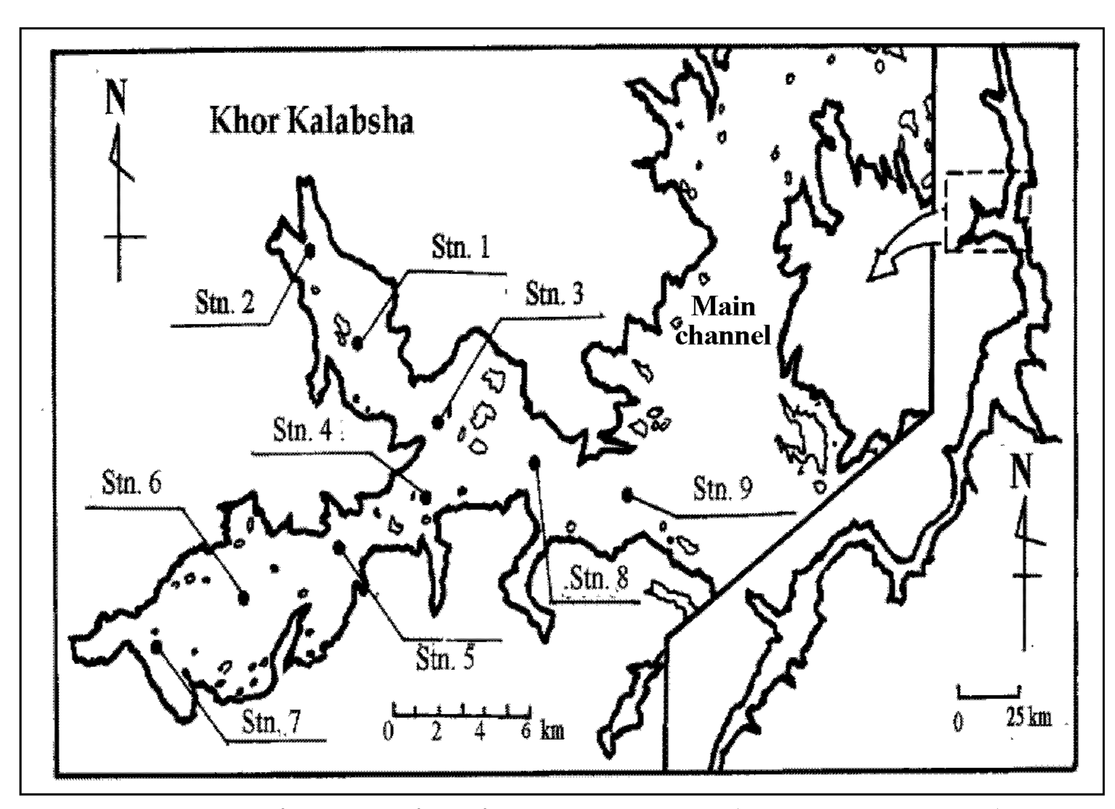


Fig. 86 **Location of stations in Khor Kalabsha (Mohamed, I. 1993c).**

Table 54 **Variations of chlorophyll *a* concentration (mg/m³) in two khors during 1986 and 1987.**

		El Ramla*	Kalabsha**
Maximum	**Value**	24.5	32.1
Conc.	**Stn.**	4	4
	Date	Nov. 86	May 86
Minimum	**Value**	3.1	2.6
Conc.	**Stn.**	10, 11	9
	Date	March 86, Feb. 87	Aug. 86
Temp. (°C)	**From**	16.0 °C	15.8 °C
	Stn.	4	6
	Date	Jan. 86	Dec. 86
	To	28.9	28.7

	Stn.	10	8
	Date	July 86	June 87
Transparency			
(range,m)	**From**	1.2	0.8
	Stn.	6	2
	Date	Aug. 87	Aug.86
	To	6.0	3.3
	Stn.	4	9
	Date	Feb. 86	Dec. 86

* For stations refer to Fig. 84 (Mohamed, I. 1993f) . ** For stations refer to Fig. 86 (Mohamed, I. 1993c).

Table 55 **Chlorophyll *a* for net and nanoplankton (μg/l) [Abdel-Monem 1995].**

Site	Depth	Winter		Spring		Summer		Autumn	
		net	nan.	net	nan.	net	nan.	net	nan.
High Dam	3 m	1.71	4.13	3.56	14.19	4.18	1.98	1.86	2.74
	15 m	1.30	5.02	1.18	2.59	1.28	2.93	1.32	3.86
	Bott.	1.68	4.22	0.85	1.62	0.06	0.36	1.22	0.37
Dihmit	3 m	0.89	3.88	1.07	4.11	4.21	2.64	0.09	6.02
	15 m	1.08	4.05	10.63	3.68	0.78	2.64	1.67	6.11
	Bott.	1.29	3.41	0.41	2.06	0.47	1.17	1.33	1.02
Kalabsha	3 m	1.05	2.85	5.84	15.16	1.27	3.67	0.53	6.41
	15 m	0.46	2.21	1.23	6.06	0.27	2.66	2.10	6.02
	Bott.	0.54	3.68	0.32	1.91	0.01	0.45	0.38	1.68
Maryia	3 m	0.95	2.66	1.47	7.63	0.54	3.86	0.10	7.48
	15 m	0.90	3.72	12.56	6.94	2.00	3.23	2.16	6.06
	Bott.	0.61	3.58	0.34	3.21	0.05	0.36	0.20	2.05
El Madiq	3 m	1.98	6.32	2.68	5.14	3.5	15.25	4.75	14.50
	15 m	0.57	2.97	1.32	7.19	1.67	5.18	3.50	15.50
	Bott.	2.08	6.22	2.61	2.38	0.02	0.52	0.17	1.57
Singari	3 m	0.93	3.11	19.00	16.75	0.29	8.02	6.25	20.00
	15 m	0.79	3.25	8.50	17.50	0.73	2.89	4.75	14.25
	Bott.	0.37	0.86	1.18	6.16	7.00	8.75	0.38	0.85
Amada	3 m	0.62	3.06	11.00	34.00	10.00	14.00	24.88	1.62
	15 m	1.30	5.28	15.26	7.24	1.51	3.28	2.64	2.64
	Bott.	0.53	2.36	0.49	3.23	0.12	0.55	1.66	0.39
Tushka	3 m	1.33	1.52	8.98	8.02	0.59	8.41	4.28	2.76
	15 m	0.63	1.25	4.94	3.86	0.83	2.23	0.66	1.49
	Bott.	0.26	0.82	1.08	2.25	0.02	0.27	0.21	0.22
Abu Simbel	3 m	0.46	1.85	32.51	23.00	9.00	29.75	2.97	2.02
	15 m	0.60	1.62	16.96	4.79	0.48	4.21	1.06	1.87
	Bott.	0.30	0.84	13.87	2.89	0.80	1.45	0.03	0.30
Adindan	3 m	0.19	1.61	12.98	16.52	7.00	13.50	2.13	1.53
	15 m	0.11	0.74	13.78	7.97	0.83	3.13	1.13	1.34
	Bott.	1.71	1.21	3.70	3.10	0.08	0.40	0.11	0.24
Average		**0.91**	**2.95**	**7.01**	**8.04**	**1.99**	**4.92**	**2.48**	**4.43**

Spring. The highest averages of chlorophyll *a* were recorded in spring as well as at most sites mostly at 3 m depth. The southern region sites attained higher chlorophyll *a* than the northern ones. The maximum value of net chlorophyll *a* (32.51 μg/l) during the year was recorded at Abu Simbel at 3 m depth.

Summer: Maximum chlorophyll *a* values were recorded in summer at most sites at 3 m depth (Table 55). The highest chlorophyll *a* values were found at Abu Simbel amounting to 9 and 29.75 μg/l for net and nanoplankton chlorophyll *a* at 3 m depth.

Autumn: Nanoplankton chlorophyll *a* was the major constituent of total chlorophyll *a* at the northern sites in autumn, while the reverse was the case at most depths at the southern region. Furthermore, higher values of chlorophyll *a* were recorded at 3 m depth except at Dihmit and Mariya. The maximum chlorophyll *a* value (26.50 μg/l) was recorded at 3 m depth at Amada composed of 24.88 and 1.62 μg/l for net and nanoplankton (Table 55).

Chlorophyll/Phaeophytin Ratio

In 1993 chlorophyll/phaeophytin ratios were calculated for net and nanoplankton (Abdel-Monem 1995) collected from ten sites in the main channel and the results indicate regional, seasonal and vertical variations. The following shows the average seasonal variations of chlorophyll / phaeophytin ratios:

	Winter		Spring		Summer		Autumn	
Average	**net**	**nano.**	**net**	**nano.**	**net**	**nano.**	**net**	**nano.**
values	0.25	0.31	0.57	0.60	0.81	0.57	0.72	0.55

The results indicate minimum values in winter and maximum in summer.

PRIMARY PRODUCTIVITY

Entz (1972) reported a value of 16 g O_2/m^2/day for Lake Nasser from a 24 h light- and dark - bottle study. Samaan (1971) estimated primary productivity at different locations of Lake Nasser by using the C_{14} method, and showed that it ranged between 0.225-2.202 g C/m^3/12 hrs. (Table 56). Fead (1980) recorded values ranging from 10.7 and 16.4 g O_2/m^2/day. During 1986/87 Habib (1998b) recorded values ranging from 1.0–27.4 and 0.7-23.8 g C/m^2/day for gross and net primary production respectively.

Table 56 **Gross primary productivity (g C/m^3/12hrs.) at different localities in Lake Nasser (Samaan 1971).**

Site	Gross primary productivity (g C/m^3/12hrs.)					
	Surface	**0.3 m**	**1m**	**2m**	**3m**	**5m**
El-Berba	1.198	---	1.486	1.284	0.797	0.295
El-Madiq	1.200	---	1.704	---	0.856	0.225
Singari	0.829	1.194	1.252	1.007	0.467	---
Khor Singari	1.224	1.962	2.202	1.097	0.487	---

It appears that the Lake water is highly eutrophic and sustains a dense crop of phytoplankton. The photosynthetic activities of phytoplankton at the surface water are inhibited by the high light intensity of solar radiation. Thus,

the highest production rate is obtained at a depth of about 1-2 m from the surface water and it decreases gradually with increasing the depth of water.

Gross primary productivity below one square meter per day (Σ gross), is controlled by the fertility of water and the depth of the photic zone, i.e. the depth of 0.5% light illumination. The depth of the photic zone ranges between 390 cm (Khor Singari) and 485 cm (El-Birba). Results of gross primary productivity in g carbon below one square meter per day (Σ gross) is given in Table 57 which also shows the optimum photosynthetic rate (A opt.) and the relation Σ gross/A opt. The results indicate that the primary productivity in Lake Nasser ranges between 3.21 and 5.23 g $C/m^2/day$. The highest primary productivity below one square metre is obtained at El-Madiq and El-Birba, while the highest fertility of the water per unit volume (A opt.) is attained at Khor Singari. The relation Σ gross/A opt. is highest at El-Birba and then decreases gradually towards the southern region due to the gradual decrease of the depth of the photic zone. Habib & Aruga (1987) estimated the primary net production at different areas of the Lake (Fig. 149 and Table 148) and found that it ranged between 2.51-5.28 with an average of 4.01 $kg/dw/m^2/year$. It appears also that a gradual eutrophication of the Lake is a result of continuous sedimentation of organic matter that accumulates on the bottom and through the annual introduction of the flood water rich in nutrients which supply phytoplankton with their inorganic requirements.

***Table** 57* **Gross primary productivity below one square metre per day (Σ gross) in g $C/m^2/day$ and optimum production rate at different localities of Lake Nasser (A opt.) in g $C/m^2/day$ (Samaan 1971).**

Site	Σ gross **g $C/m^2/day$**	A opt. **g $C/m^2/day$**	Σ gross/A opt.
El-Birba (El Ramla)	4.840	1.486	3.25
El-Madiq	5.230	1.707	3.05
Singari	3.210	1.252	2.56
Khor Singari	4.340	2.020	2.15

In 1993 Abdel-Monem (1995) measured the primary productivity (using light and dark bottle C^{14} method) and the photosynthetic capacity (assimilation number) in the main channel of the Lake at 3 and 15 m depth at ten localities and his results (Table 58) indicate the following:

1- The primary productivity ranged from 2.72 mg $C/m^3/h$ at 3 m depth at the High Dam site in summer to 179.91 mg $C/m^3/h$ at Dihmit in spring at the same depth. At 15 m depth the primary productivity ranged between 0.0 (at most sites) in winter to 128.15 $mgC/m^3/h$ in summer at Mariya.

Table 58 **Primary productivity (P.p) (mg C/m^3/h) and assimilation number (As.no) (mg C/mg chl/h) at various sites of Lake Nasser along the main channel (Abd El-Monem 1995).**

Site	Winter				Spring				Summer				Autumn			
	3m		15m		3m		15m		3m		15m		3m		15m	
	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no
High Dam	45.20	9.34	0.00	0.00	95.93	5.40	14.00	3.71	2.72	0.44	33.21	7.89	30.26	11.04	9.56	2.48
Dihmit	4.36	0.91	0.00	0.00	179.91	34.73	0.00	0.00	46.25	6.75	15.24	4.46	30.83	5.12	1.56	0.26
Kalabsha	7.93	2.03	0.00	0.00	40.65	1.94	0.00	0.00	91.27	18.48	71.54	24.42	9.45	1.47	1.52	0.25
Maryia	34.26	9.49	0.00	0.00	100.93	11.09	4.00	0.21	24.92	5.66	128.15	24.50	12.45	1.66	12.19	2.01
El-Madiq	11.90	1.43	0.00	0.00	37.20	4.76	41.21	0.00	15.02	0.80	48.96	7.15	7.62	0.53	7.45	0.48
Singari	9.48	2.35	0.00	0.00	26.22	0.73	45.03	1.73	6.16	0.74	0.00	0.00	9.35	0.47	10.67	0.75
Amada	8.25	2.24	0.00	0.00	125.13	2.78	106.13	4.72	2.87	0.12	7.44	1.55	28.69	17.71	14.90	5.64
Tushka	13.92	4.88	0.00	0.00	16.47	0.97	0.00	0.00	12.39	1.38	0.00	0.00	21.82	7.91	4.26	2.86
Abu Simbel	10.94	4.74	23.87	10.75	43.27	0.78	28.26	1.30	29.38	0.77	0.00	0.00	14.90	7.38	8.73	4.67
Adindan	4.32	2.40	0.00	0.00	22.29	0.76	29.66	1.36	11.24	0.55	47.99	12.12	30.49	19.93	42.61	31.80
Average	15.06	3.98	2.39	1.08	68.80	6.39	26.83	1.30	24.22	3.57	35.25	8.21	19.59	7.32	11.35	5.12

Comparable results were obtained in 1996 (SECSF 1996) which showed that primary productivity fluctuated between 7.5 $mgC/m^3/h$ at 3 m depth at Abu Simbel in autumn to 249 $mgC/m^3/h$ at the same depth at Korosko during winter. In deeper waters (6-12 m) the range was from 45 $mgC/m^3/h$ at the High Dam site in autumn to 247.5 $mgC/m^3/h$ at Korosko in winter.

2- The highest average annual primary productivity at 3 m depth recorded in the main channel during 1993 was 68.80 $mgC/m^3/h$ in spring, and the lowest value (15.06 $mgC/m^3/h$) was recorded in winter at the same depth. At 15 m depth the average maximum primary productivity was 35.25 $mgC/m^3/h$ recorded in summer, while the minimum (2.39 $mgC/m^3/h$) was found in winter.

3- The photosynthetic capacity (assimilation number) ranged from 0.76 mg C/mg Chl/h in spring at 3 m depth at Adindan, to 34.73 mgC/mg Chl/h at Dihmit in spring at the same depth. At 15 m depth the photosynthetic capacity ranged from 0.0 (at most sites) in winter to 31.80 mg C/mg Chl/h at Adindan.

4- At 3 m depth the maximum annual average of photosynthetic capacity was 7.32 mg C/mg Chl/h in autumn, and the minimum (3.57 mg C/mg Chl/h) was recorded in summer. At 15 m depth the highest value (8.2 mg C/mg Chl/h) was found in summer, and the lowest (1.08 mg C/mg Chl/h) was recorded in winter.

5- There is no parallelism between primary productivity and photosynthetic capacity. Thus, high primary productivity do not always correspond to high photosynthetic capacity.

EPIPHYTES

Epiphytic algae are among the most important food items for the tilapias which constitute the major fish species of Lake Nasser. In Lake Nasser the attached algae are Chlorophyceae, Bacillariophyceae and Dinophyceae. Mohamed, I. (1993d) studied the attached algae at nine different areas of Lake Nasser, and calculated chlorophyll *a* concentration and his results are presented in Tables 59 and 60. The results indicate the presence of 14 algal species belonging to 3 major groups (Table 59). In 1989/91 Habib (1997) recorded 28 species of attached algae at four localities in Lake Nasser.

Studying the distribution of attached algae along 9 localities indicates that Abu Simbel, Marwaw, and Eneba are richer in number of species (i.e. 4-5 spp.) than other localities (Tushka and Allaqi 2 spp.) while other localities contain only one species (Table 60 – Mohamed I. 1993d).

Table 59 **Attached algae recorded in Lake Nasser during 1989-1991 (Mohamed, I. 1993d).**

Chlorophyceae	Bacillariophyceae	Dinophyceae
Cladophora sp.	*Cyclotella* sp.	*Ceratium* sp.
Cosmarium sp.	*Cymbella* sp.	*Peridinium* sp.
Oedogonium sp.	*Diatoma* sp.	
Pediastrum sp.	*Melosira* sp.	
Scenedesmus sp.	*Navicula* sp.	
Spirogyra sp.	*Synedra* sp.	

Table 60 **Distribution of the common attached algae in different areas (Mohamed, I. 1993d).**

Site	Attached Algae
Abu Simbel	*Oedogonium* , *Pediastrum* , *Cladophora* and *Melosira* spp.
Tushka	*Oedogonium* and *Pediastrum* spp.
El-Ramla	*Oedogonium* sp.
Marwaw	*Oedogonium* , *Spirogyra* , *Cladophora* , *Melosira* and *Navicula* spp.
Eneba	*Cladophora, Spirogyra, Navicula* and *Diatoma* spp.
Wadi El-Arab	*Oedogonium* sp.
Sayala	*Melosira* sp.
Dihmit	*Spirogyra* sp.
Allaqi	*Spirogyra* and *Synedra* spp.

The maximum chlorophyll *a* concentration of the attached algae (101.4 mg/m^2) was recorded at Eneba in December 1989, while the minimum values (2.0-2.2 mg/m^2) were recorded at Allaqi in July and August 1991 (Table 61). In Tushka, the concentration of chlorophyll *a* of the attached algae was recorded as 82.2 mg/m^2 in November 1989 (Table 61).

Table 61 **Chlorophyll *a* concentration of the attached algae (Mohamed, I. 1993d).**

Value Degree	Concentration (mg/m^2)	Area	Sampling Date
Maximum	101.4	Eneba	December, 1989
High	82.2	Tushka	November, 1989
Minimum	2.0 and 2.2	Allaqi	July and August, 1991

FUNGI (MYCOFLORA)

Aquatic Phycomycetes from Surface Water Samples

El-Hissy *et al.* (1996) recorded 25 identified and 4 unidentified species which belong to eleven genera of aquatic fungi from water samples collected from Lake Nasser (Table 62). The occurrence of the aquatic fungal genera was in the following descending order: *Saprolegnia, Pythium, Aqualinderella, Achlya, Aphanomyces, Blastocladiopsis, Pythiopsis, Dictyuchus, Blastocladia, Allomyces* and *Leptomitus.*

The relation between the different water characteristics versus the number of aquatic fungal genera and species is highly significant (El-Hissy *et al. 1996).* The latter authors mentioned that temperature is the major factor conversely affecting the number of genera and species with a relative efficiency of 48.13% and 36.18% respectively. This observation is in agreement with Dick (1971), Föhn (1973), Tomlinson & Williams (1975), El-Hissy (1979) and Rattan *et al.* (1980).

The total soluble salts constitute the second factor affecting the number of genera and species with a relative efficiency of 13.12% and 19.15% respectively and the relation is a positive one (El-Hissy *et al.* 1996). However, these results are in contrast with those obtained by Scholz (1958), Fuller *et al.* (1984), Amon (1978) and Amon & Yei (1982).

The pH values showed a negative correlation with the number of genera and species with a relative efficiency of 3.32 % and 3.94% respectively (El-Hissy *et al.* 1996). This agrees with the results obtained by Lund (1934). However, many authors (e.g. El-Hissy *et al.* 1982, 1992, El-Hissy & El-Nagdy 1983, Paul *et al.* 1984) mentioned that pH value is not a major factor governing the distribution and occurrence of aquatic phycomycetes.

Previous studies indicate that there is no clear relationship between the occurrence of aquatic fungi and the fluctuations in the amount of dissolved oxygen (Alabi 1971, Rattan *et al.* 1980 and El-Hissy *et al.* 1996). However, Misra (1980) and El-Hissy & Khalil (1989) found a close relationship between the dissolved oxygen of water and the occurrence, seasonal changes and zoosporic production of aquatic fungi.

The organic matter content of the tested water samples showed also a limited influence on the number of aquatic fungal genera and species (0.27% and 0.76% respectively) (El-Hissy *et al.* 1996).

The richest water samples in aquatic phycomycetes species were those characterized by relatively low temperatures (15.9 - 20.3 °C), and pH ranging between 7.4-8.3, dissolved oxygen ranging from 5.2 to 9.3 mg/l and total soluble salts ranging from 208.0 to 254.0 mg/l. The poorest samples were characterized by relatively high temperatures (20.6-33.1°C), pH values fluctuating between 6.3 and 9.2, dissolved oxygen varying from 4.5 to 10.6 mg/l, total soluble salts ranging from 149 to 175 mg/l, and the organic matter content between 12.0 and 51.1 mg/l (El-Hissy *et al.* 1996). *Saprolegnia* and *Pythium* were the most frequent aquatic fungal genera recovered by El-Hissy *et al.* (1996), whereas *Aphanomyces, Dictyuchus, Pythiopsis, Leptomitus, Allomyces* and *Blastocladiopsis* were less frequent.

Vertical Fluctuations of Mycoflora

Of the mesophilic fungi Moharram *et al.* (1990) recorded a total of 60 species and one variety related to 22 genera from both water (48 species, 1 variety and 16 genera) and bottom mud samples (40 species, 1 variety and 17 genera) from Lake Nasser and pointed out that the fungal population of Lake Nasser showed marked vertical variations during the period from July 1985 to December 1986. High fungal counts were recorded at the surface waters which were mainly due to the high counts of *Aspergillus fumigatus* and *A. terreus*. Going deeper, the fungal population decreased till 30 m, then gradually increased to reach its maximum at 70 m depth (Moharram *et al.* 1990). The latter authors attributed such increase to the high population of *Penicillium funiculosum*. At each sampling time, the water temperature and the values of dissolved oxygen were always higher at the surface than near the bottom of the Lake. The temperature ranged from 15 to 26 °C and the dissolved oxygen from 1.31 to 8.98 mg/l (Moharram *et al.* 1990).

***Table** 62* **Frequency of occurrence of aquatic fungi of water samples and submerged mud samples collected from Lake Nasser (El-Hissy *et al.*1996 and 1997).**

Aquatic fungal genera and species	Occurrence remarks	
	Fungi from surface water samples (El-Hissy *et al.* 1996)	Fungi from submerged mud samples (El-Hissy *et al.* 1997)
Achlya	L	L
A. dubia	R	R
A. hypogyna	R	-
A. proliferoides	-	R
A. racemosa	-	R
Achlya sp.	R	R
Aphanomyces	R	R
A. laevis	R	R
A. norvegicus	R	R
A. scaber	R	-
Aphanomyces sp.	R	R
Dictyuchus	R	R
D. carpophorus	R	R
D. sterilis	R	R
D. monosporus	-	R
Leptolegnia	-	R
L. caudata	-	R
Pythiopsis	R	R
P. cymosa	R	R
P. humphreyana	R	R

Cont. ***Table 62***

Saprolegnia	M	M
S. anisospora	R	R
S. diclina	R	R
S. ferax	R	R
S. hypogyna	R	R
S. parasitica	R	R
Saprolegnia sp.	L	L
Leptomitus	R	R
L. lacteus	R	R
Aqualinderella	L	L
A. fermentans	L	L
Pythium	M	M
P. debaryanum	R	-
P. irregulare	R	-
P. pulchrum	R	R
P.rostratum	R	R
P. ultimum	R	R
P. vexans	R	R
P. thalassium	-	R
P. undulatum	-	R
Pythium sp.	R	R
Allomyces	R	-
A. arbuscula	R	-
Blastocladia	R	-
B. angusta	R	-
Blastocladiopsis	R	R
B. parva	R	R
Nowakowskiella	-	R
N. elegans	-	R

H = High occurrence; more than 50%, M = Moderate occurrence, between 25-50 %, L = Low occurrence, between 12-24%, R = Rare occurrence, less than 12%, - = not recorded

Monthly Variations of Mycoflora

El-Hissy *et al.* (1990) recorded 51 species and one variety belonging to 21 genera of mesophilic fungi from the monthly samples of marginal water (44 species, 1 variety and 18 genera) and submerged mud (78 species, 1 variety and 30 genera) of Lake Nasser during the period from July 1985 to December 1986. The most common species were *Aspergillus fumigatus, A. flavus, A. terreus, A. niger* and *Penicillium funiculosum* (El-Hissy *et al.* 1990). The latter authors found that the highest fungal populations were detected either in October, December 1985 or February 1986. Of the 12 thermophilic and thermotolerant fungal

species, *Aspergillus fumigatus* and *A. nidulans* were common in the bottom mud but were completely missing at the various vertical strata of the Lake. *Paecilomyces variotii, Rhizomucor pusillus, Thermomyces lanuginosus, Thermoascus thermophilus* and *Sporotrichum thermophilum* appeared in moderate or low incidences in one site or more. El-Hissy *et al.* (1990) compared the mycoflora of submerged mud with the one recorded from water samples, and found a high degree of similarity.

Aquatic Fungi from Submerged Mud

El-Hissy *et al.* (1997) recorded 25 identified and 4 unidentified aquatic fungal species belonging to 11 genera of aquatic fungi from submerged mud collected randomly from the margins at different localities of Lake Nasser banks during the period from May 1992 to October 1992 (Table 62). The richest submerged mud samples in aquatic fungi were characterised by somewhat alkaline pH ranging between 7.1 and 7.9 and by low amounts of total soluble salts (1.9-2.9 mg/100 g mud sample) and low organic matter (1.6-1.9 mg/100g) (El-Hissy *et al.* 1997). The latter authors showed that approximately 54 % of the mud samples yielded only one aquatic fungal species per sample. *Pythium* and *Saprolegnia* were the most frequent aquatic fungal genera, whereas *Leptomitus* and *Nowakowskiella* were less frequent.

BACTERIA

Total Bacterial Counts (TBC) at 22 and 37 °C

Bacteria developing at 22 °C are saprophytic and their counts afford some indication of the amount of food substances available for bacterial nutrition and the amount of soil and other extraneous materials that water gained. On the other hand, bacteria developing at 37 °C are mainly parasitic, derived from soil or excretal material (APHA 1975). The ratio of colony counts at these two temperatures helps to explain any sudden fluctuation in bacterial counts, the wider the ratio, the more probable bacteria are related to soil or water saprophytes and therefore of minor health significance. In unpolluted water this ratio ranges from 1 to 10, while in polluted waters, it is generally less than one.

Elewa and Azazy (1986) studied the seasonal variations of the total bacterial counts (TBC) at four sites in Lake Nasser (High Dam, Allaqi, Amada and Abu Simbel) during 1974 and the drought period in 1984. Their results (Table 63) indicate regional, seasonal and yearly variations in TBCs. Thus the lowest total bacterial counts at 22 and 37 °C were recorded in winter, while the maximum values were in summer, mainly due to the renewal of nutrients carried by floods and to enrichment of the Lake with organic matter as a result of dead phytoplankton and decaying submerged vegetation. Furthermore,

there was a gradual decrease of TBCs from south to north, with a further increase near the HD, which may be due to decayed materials as a result of fisheries activities.

The results (Table 63) indicate that the total bacterial counts in 1984 increased in comparison to those recorded in 1974, being parallel with the values of organic carbon. This may be attributed to the activity of the phyto- and zooplankton, and/or relative concentration of bacterial densities related to decreased water flow from the south (Elewa & Azazy 1986).

In 1996 (SECSF 1996) bacteriological studies were carried out in the main channel of Lake Nasser at nine sites in winter, spring and autumn. The results of total bacterial counts (TBCs) at 22 °C showed maximum values during spring at all sites ranging from $230x10^5$/ml at Abu Simbel to $1870x10^5$/ml at Kalabsha. At 37 °C the range was $100x10^5$/ml at Allaqi to $520x10^5$/ml at El Ramla. The minimum values developed at 22 and 37 °C were found in autumn ranging from 0.04 $x10^5$/ml at El-Madiq to $0.85x10^5$/ml at Abu Simbel (Table 64) and 0.04 $x10^5$/ml at Amada to $0.47x10^5$/ml at Korosko, respectively.

At the khors the total number of bacteria developed at 22 and 37 °C at surface waters in winter were higher than those recorded in the main channel. The maximum values recorded in spring ranged from $961x10^5$/ml at Khor Allaqi to $330x10^5$/ml at Khor Kalabsha near the bottom. The least number was found in autumn, ranging from $0.06x10^5$/ml at Khor Allaqi to $0.666x10^5$/ml at Khor Tushka near the bottom (SECSF 1996).

Comparing the results obtained by Elewa & Azazy (1986) in 1974 and 1984 with those recorded in 1996 (SECSF 1996) by choosing four sites for both studies (Table, 63), the following is observed:

1. A remarkable increase of the total bacterial counts in the last two decades is observed at all sites for both bacteria developed at 22 and 37 °C, amounting to more than 1000 folds.

2. High values were recorded, usually near the High Dam.

3. In winter 1996 there was a tendency of increase of the total bacterial count at 22 and 37 °C from north to south, while the reverse was true in autumn.

4. When considering the ratio of TBCs at 22 and 37 °C it was found that in 1974, 1984 and 1996 these ratios were above one, being narrower in summer and wider in winter and spring. In 1996 the ratio was less than those estimated in 1974 and 1984, except in autumn where the ratio was much higher. Thus it seems that Lake Nasser is still unpolluted and the low ratio values in winter

and spring 1996 (summer not recorded) may be due to eutrophication of the Lake.

Table 63 **Seasonal variations of total bacterial counts (TBCs) at 22 and 37 °C during 1974, 1984 (C/ml) and 1996 ($Cx10^5$/ml) in the main channel of Lake Nasser .**

Site	Year	Winter		Spring		Summer		Autumn	
		22 °C	37 °C	22 °C	37 °C	22 °C	37 °C	22 °C	37 °C
High Dam	**1974**	187	73	414	188	3730	2520	743	673
	1984	340	290	750	360	5100	4400	1800	1200
	1996	156	13	294	298	--	--	0.22	0.15
Allaqi	**1974**	175	63	238	87	2700	2450	460	383
	1996	14	10	133	100	--	--	0.39	0.12
Amada	**1974**	168	66	322	90	2680	2400	720	705
	1996	14.2	8.5	551	372	--	--	0.44	0.04
Abu Simbel	**1974**	172	68	421	192	4820	3510	710	637
	1996	5.16	4.3	230	200	--	--	0.85	0.316

(-- = not recorded)

Counts of both asymbiotic nitrogen fixers: the aerobes *Azotobacter* and the anaerobes, N_2-fixing clostridia, tended to decrease in 1984, compared with in 1974. This was attributed to the drought and less suspended matter reaching from the south, which might carry these organisms in flood water (Elewa & Azazy 1986).

Counts of nitrifying bacteria in 1984 showed a relative increase in comparison to those previously recorded in 1974. This might be due to the increase in the nitrifying activity related to the higher activity of the total bacterial load. This is confirmed by the remarkable increase in the nitrate content in the water of the Lake after the drought period. Thus, in 1984 the nitrate concentration ranged from 0 to 290 μg/l, as compared to 64 – 72 μg/l in 1974 (Elewa & Azazy, 1986). The zero value of nitrate concentration recorded in spring 1984 was correlated with the high photosynthetic rate of phytoplankton.

Considering pH values of Lake Nasser, it is noticed that upon storage in the reservoir a remarkable increase of pH (i.e. 8.89) was recorded in spring 1984, compared to pH 7.85 in autumn 1974. This may be attributed to the increasing photosynthetic activity, consuming free CO_2 from CO_3^{-3} and HCO^{-3} buffer system. This confirms that eutrophication of Lake Nasser is taking place. Hutchinson (1957) indicated that pH of productive lakes goes parallel with oxygen mainly in spring, the decrease in oxygen is related to a decrease of pH.

Purple Non-Sulfur Bacteria (Rhodospirillaceae)

Shoreit *et al.* (1989) recorded 485 isolates from different localities of Lake Nasser in summer 1984 to spring 1985 and found that these isolates comprise 5 genera with 8 species of purple non-sulfur bacteria. *Rhodopseudomonas* was the most common genus at all sites, represented by 3 species: *R. acidophila, R. blastica* and *R. palustris. Rhodomicrobium* was next in frequency, represented by *R. vannielli* only. This species was only recorded from khor sites (Fig. 87). *Rhodocyclus* was represented by 2 species, *R. gelatinosus* and *R. tenuis. Rhodobacter* and *Rodospirillum* were represented by one species each, *Rodobacter capsulatus* and *Rodospirillum rubrum.* Khor sites were richer in the number of isolates and genera of purple non-sulfur bacteria than the main body of Lake Nasser (Fig. 87).

The superior nitrogen-fixing Rhodospirillaceae from Lake Nasser were *Rhodocyclus gelatinosus* and *Rhodomicrobium vannielii* followed by *Rhodobacter capsulatus, Rhodopseudomonas viridis* and *Rhodopseudomonas palustris* (Shoreit *et al.* 1992). High and moderate nitrogenase activities (534 to 1528 n mol ethylene produced/4 ml/h) were found in 56% of the isolates (total 32), while the remainder showed low activities (76 to 477 n/mol ethylene produced /4 ml/h).

Purple non-sulfur bacteria in Lake Nasser exhibit seasonal and regional distribution. Thus *Rhodobacter capsulatus* was recovered more often in autumn, winter and spring 1985 than in summer 1984. Furthermore, it was more common in khors than in the main channel of the Lake, while *Rhodospirillum rubrum* was more common in summer than in winter and spring (Shoreit *et al* 1989). The latter authors point out that investigations are in progress to follow changes which are expected to take place with the long storage of water and their effect on occurrence and composition of photosynthetic bacteria.

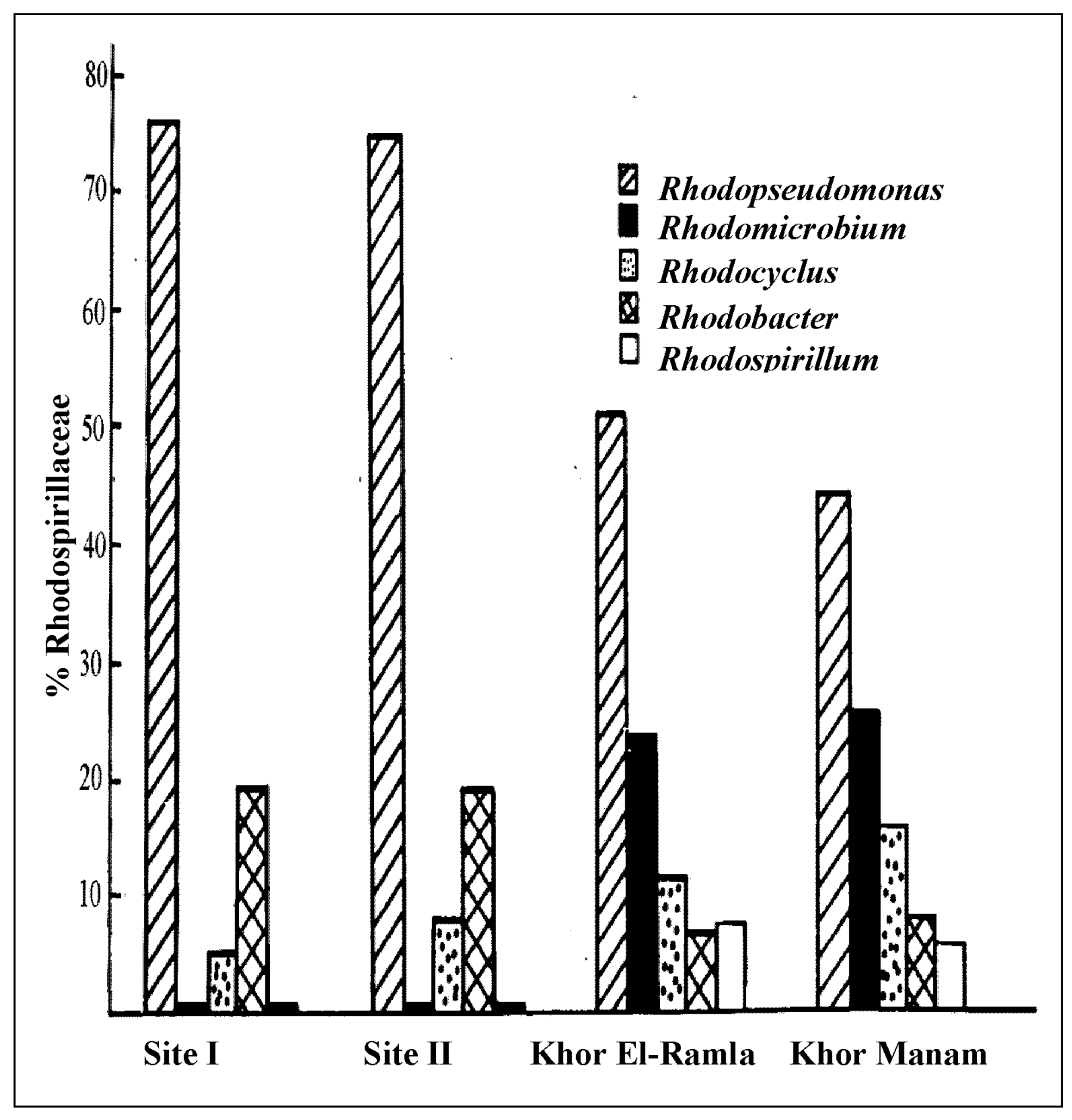


***Fig.** 87* **Percentage of genera of Rhodospirillaceae recovered in different localities (Sites I and II in the main channel) (Shoreit *et al.* 1989).**

Coliform and Faecal Coliform Bacteria

In 1996 (SECSF, 1996) investigations were carried out at nine sites along the main channel of Lake Nasser and five Khors (El Ramla, Kalabsha, Allaqi,

Korosko and Tushka) in winter, spring and autumn, to determine the total number of coliform and faecal coliform bacteria. The results (Table, 64) indicated the following:

The main channel

(a) The highest number of faecal coliform bacteria ($330x10^3$/100 ml) was recorded near the High Dam in winter. At other sites it seems that the faecal coliform bacteria were also high in winter ranging from 0.17 to $17x10^3$/100 ml, and low in autumn (range 0.0 to $0.035x10^3$/100 ml).

(b) The total number of coliform bacteria was remarkably high ($540x10^3$/100 ml) near the High Dam in winter. Similar to the faecal coliform, the total

Table 64 **Total counts of bacteria ($Cx10^5$/ml) and the probable number of coliform and faecal coliform bacteria ($Cx10^3$/100 ml) in the main channel and Khors of Lake Nasser during 1996 (SECSF 1996).**

Site		Winter				Spring				Autumn			
		Coliform		Total count at		Coliform		Total count at		Coliform		Total count at	
		Faecal	Total	22 °C	37 °C	Faecal	Total	22 °C	37 °C	Faecal	Total	22 °C	37 °C
High Dam		330	540	15.6	13	0.2	0.4	294	298	0.035	0.05	0.28	0.18
El-Ramla		0.23	32	9	8.8	0.11	0.17	1850	520	00	0.002	0.3	0.12
Kalabsha		40	46	4	3.7	0.17	0.55	1870	2.7	0.11	0.014	0.12	0.06
Allaqi		0.17	0.22	14	10	0.25	0.35	133	100	0.225	0.55	0.39	0.12
El-Madiq		0.17	2.0	0.96	17.8	0.08	0.17	572	400	00	00	0.04	0.30
Korosko		0.33	0.48	15.7	2	0.002	0.005	567	393	0.002	0.005	0.26	0.47
Amada		0.23	0.54	14.2	8.5	0.002	0.008	551	372	00	0.005	0.44	0.04
Tushka		3.3	4	8.46	3.3	0.002	0.007	447	320	0.005	0.017	0.21	0.6
Abu Simbel		17	26	5.16	4.3	0.13	0.02	230	200	0.17	0.55	0.85	0.316
Khor El-Ramla	**Surface**	0.2	50	8.6	35.7	0.008	0.05	142	121	0.0	0.002	0.58	0.14
	Bottom	0.9	54	10	57	0.175	0.02	200	133	0.14	0.225	0.06	0.10
Khor Kalabsha	**Surface**	3.2	49	1.33	1	0.025	0.250	777	393	00	0.002	0.42	0.30
	Bottom	9	90	4.1	3.3	0.2	0.275	330	242	00	00	0.44	0.10
Khor Allaqi	**Surface**	0.22	40	22.1	18	0.002	0.017	933	650	0.002	0.002	0.64	0.06
	Bottom	0.46	45	8	50.6	0.045	0.200	961	680	0.002	0.004	0.08	0.16
Khor Korosko	**Surface**	0.11	11	18.2	16	0.005	0.11	550	400	00	0.002	0.12	0.35
	Bottom	0.32	20	114	90	0.035	0.20	590	480	00	0.002	0.30	0.32
Khor Tushka	**Surface**	0.2	0.7	60	35	0.025	0.14	356	349	0.017	0.050	0.53	0.65
	Bottom	0.9	5.4	182	59	0.04	0.2	378	354	0.02	0.05	0.72	0.66

number of coliform bacteria was highest in winter at other sites but with lesser values ranging from $0.22x10^3$/100 ml at Allaqi to $46x10^3$/100 ml at Kalabsha.

Minimum values were recorded in autumn ranging from 0.0 at El-Madiq to $0.550x10^3$/100 ml at Abu Simbel.

The khors

(a) The numbers of coliform and faecal coliform bacteria were higher at the bottom than at the surface.

(b) In autumn certain Khors (Kalabsha and Korosko) were devoid of both types of bacteria, and when present in other Khors they were found in small numbers.

CONCLUSIONS

Macrophytes

Eleven macrophytic euhydrophytes (flowering and non flowering) were recorded from Egyptian Nubia pre- and post completion of the Aswan High Dam. Two euhydrophytic species have been lost after Lake Nasser formation, i.e. *Alisma gramineum* and *Damasonium alisma* Mill. var. *compactum.* Ten species were recorded from the Lake since its filling, including 5 cosmopolitan species: *Potamogeton crispus, P. pectinatus, Najas marina* subsp. *armata; Zannichellia palustris* and *Nitella hyalina* (an alga); and 4 subcosmopolitan species: *Potamogeton trichoides, P. lucens, Vallisneria spiralis* and *Najas horrida.* Recently, *Myriophyllum spicatum* was recorded from the Lake. Three species of *Potamogeton*: *P. crispus, P. trichoides* and *P. pectinatus*, recorded during the seventies and early eighties, are no longer observed in recent years.

Najas marina subsp. *armata* dominates the deep water zone at most sites and to a lesser extent in shallow water. *Vallisneria spiralis* dominates the submerged macrophytes especially at Amada. *Zannichellia palustris*, although widely spread in Lake Nasser but not forming dense stands, is found in shallow waters. *Potamogeton lucens* is found in small stands in the northern sector of the Lake. *Najas horrida* is abundant in the shallow waters of numerous khors of the Lake, often codominant with *Najas marina* subsp. *armata.* The alga *Nitella hyalina* grows in Lake Nasser not to any great depth in open sunny positions. It often grows on calcareous sand at Lake edges.

Up to the present no floating weeds are recorded in Lake Nasser although some of them, e.g. *Eichhornia crassipes* and *Pistia stratioles* are widely spread both upstream and or downstream. There is a possibility of their future appearance in the Lake and being mostly disadvantageous, so measures must be taken to prevent their spread.

Hall *et al.* (1969) listed 4 species of genus *Najas* within the Volta Basin, including the widespread weed *Najas pectinata.* The latter weed is a potentially troublesome aquatic plant. The latter authors mentioned *Eichhornia crassipes* as one of three weeds, which have caused trouble in Volta Lake (Ghana).

Therefore, in Lake Nasser, it is necessary to keep an eye against the introduction (accidental or intentional) of *Eichhornia crassipes.* It is advised to maintain a stock of dredgers and spraying equipment and a range of herbicides in case of an outbreak. Rapid total elimination from the outset will save much expense in the long run. Heinen (1965) recommended a poster campaign to acquaint local people with the appearnce of *Eichhornia.*

Algae

In the early stages of Lake Nasser (1971) 27 species of **phytoplankton** were recorded. During the period 1981-1993, 135 species belonging to 5 classes were recorded: 54 spp. Chlorophyceae; 34 spp. Cyanophyceae; 33 spp. Bacillariphyceae; 13 spp. Dinophyceae and 1 sp. Euglenophyceae. Phytoplankton community in Lake Nasser is rich both in density and biomass. Numerically, the standing crop increases southwards from 3.405×10^6 algal units/l at El-Birba to 15.272×10^6 algal units/l at Adindan. The average density of phytoplankton is 6.258×10^6 algal units/l in surface water; while it is 2.081×10^6 algal units/l at 20 m depth. The phytoplankton biomass attains annual averages of 22.913 and 4.088 mg/l in the surface water and at 20 m depth respectively.

Diatoms and blue-green algae are the dominant groups which exhibit seasonal and local distribution. Diatoms preponderate mainly over Cyanophyceae (Cyanobacteria) along the main channel and all areas as they are well adapted to the new environment.

A marked increase of phytoplankton (upper 10 m) starting from the High Dam (average 2.707×10^6 algal units/l) to Kalabsha (average 3.44×10^6 algal units/l) was recorded. Then the number of phytoplankton decreased from El-Madiq and attained minimum values at Adindan (0.948×10^6 algal units/l). The average highest phytoplankton density was recorded in August (1976), being $4.7\text{-}9.5 \times 10^6$ algal units/l. During flood time, flood waters push great amounts of phytoplankton to the northern region of the Lake. At the southernmost station (Adindan) the lowest phytoplankton densities were recorded during flood and post-flood season.

Phytoplankton exhibit vertical distribution (during October 1979), where the density remains, more or less, constant at the northern stations (from the High Dam to Kalabsha). At Amada higher values were recorded at 3 m depth, mainly of Cyanophyceae. At El-Madiq and Abu Simbel phytoplankton density during summer and autumn was higher at surface waters compared with subsurface ones. At Adindan, the highest density was recorded at one m depth and the least at the surface and 10 m depth. During thermal stratification (late

spring, summer and early autumn) phytoplankton in Lake Nasser exhibit vertical variations. Diatoms mainly *Cyclotella* spp. and blue-green algae mainly *Anabaenopsis* sp. are the most dominant.

There is an inverse relationship between algal development and dissolved nitrate nitrogen. During August (1976) Cyanophytes were most common (71.2-89%) in the northern stations (High Dam to Amada), while diatoms were of minor importance (2.7%). In the southern stations (Tushka and Adindan) the reverse was the case, where diatoms were dominant (92.3-98.0%) and Cyanophytes constituted low percentages (0.9-7.0%). Chlorophytes remained at low concentrations throughout the Lake.

Khors sustain higher phytoplankton densities than in the main stream. Thus, the average values were 3.622×10^6 algal units/l and 5.234×10^6 algal units/l at Khor Kalabsha and Khor Singari respectively. Furthermore southern khors are more productive than the northern.

Water blooms occur occasionally (1987 to 1992) in Lake Nasser, in limited areas of the southern region. Recently it occurs intermittently all the year round and throughout the Lake. Water blooms are caused by flourishing of Cyanophyceae species leading to the formation of crusts and scums, where plants die quickly and disintegrate in intense sunlight causing oxygen depletion. In water blooms *Microcystis aeruginosa* is the dominant species in all cases, followed by *Nostoc* spp. and *Oscillatoria* spp. The latter species was recorded in remarkable quantities in Korosko, and *Aphanocapsa* spp. at Abu Simbel. During the period of 1987-1992 only six water blooms were recorded.

The southern region of the Lake shows high mean values of **chlorophyll *a*** concentrations than in the northern region. The highest concentration is recorded at Abu Simbel in the main stream prior to the annual flood. The highest values of chlorophyll *a* concentrations are recorded at 2 to 4 m depth and gradually decrease with depth.

There is no distinct seasonal variation of chlorophyll *a* concentrations in the northern stations; while marked seasonal variations are found in the southern region. Chlorophyll *a* concentration in the main channel shows seasonal changes with high values during the high temperature period, and low values during the low temperature period. This is paralleled with Secchi disk depth being highest during the low temperature period and lowest during the high temperature period and high chlorophyll *a* concentration.

Relationships between chlorophyll *a* concentration and Secchi disk depths seem to be exponential on a semilogarithmic plot, as reported by several investigators in various waters. Positive correlation is observed between chlorophyll *a* concentration and suspended solids. Positive correlation with

considerable scattered data points is noticed between chlorophyll *a* concentration and particulate organic matter.

Chlorophyll *a* concentrations are generally high inside khors than at their entrance or in the main channel, except during winter in Khor El Ramla where the reverse is true. Khor Kalabsha located in the southern region is more productive than Khor El Ramla located in the northern region. Chlorophyll *a* concentrations in khors follow the same trend as in the main channel, attaining their maximum values during spring and summer, and reaching their minimum during winter. In khors there is no wide horizontal variation of chlorophyll *a* concentrations inside, outside or at the entrance of khors, except during spring (March-April), where remarkable variations are recorded. It seems that the maximum chlorophyll *a* concentration in khors during successive years (1982-1988), is, more or less constant.

Both relationships of chlorophyll *a* to the Secchi disk depth inside and outside the khors are exponential, when plotted on a normal diagram in a similar manner as reported in both freshwater lakes and in marine waters.

Nanoplankton (<20 μm) constituted the major component of total chlorophyll *a* along the main channel with few exceptions, where chlorophyll *a* of net plankton was dominant. Maximum values for chlorophyll *a* of net and nanoplankton were recorded in spring and the minimum in winter. There were seasonal, regional and vertical variations of nanoplankton chlorophyll *a*. During winter, chlorophyll *a* concentrations were higher at the northern region than at the southern, but in spring the reverse was true.

Studies on **primary productivity** of Lake Nasser showed that it is eutrophic with highest productivity at 1-2 m depth. Gross primary productivity below 1 m^2 (Σ gross g $C/m^2/day$) ranged from 3.2 to 5.23, while optimum productivity (A opt.) ranged between 1.25 and 2.02 g $C/m^2/day$. The relation between gross primary productivity (Σ gross) and optimum production (A opt). - Σ gross/A opt. - is highest at El-Birba then decreases gradually towards the southern region due to the gradual decrease of depth of the photic zone. Gradual eutrophication of Lake Nasser may be a result of continuous sedimentation of organic matter which accumulates annually with flood water rich in nutrients.

Studies on primary productivity of Lake Nasser – during recent years - along the main channel showed that it ranged from 179.91 in spring at Dihmit to 2.72 mg $C/m^3/h$ in summer at the High Dam at 3m depth. The highest average primary productivity (68.80 mg $C/m^3/h$) was recorded in spring, the lowest (2.39 mg $C/m^3/h$) in winter. The maximum average value of

photosynthetic activity was recorded in summer at 15m depth (8.21 mg C/mg Chl/h) and the minimum in winter (1.08 mg C/mgChl/h).

Of the **epiphytic algae** - which constitute the most important food items of tilapias - 28 algal species were recorded, belonging to 4 major groups : Chlorophyta, Cyanophyta, Bacillariophyta and Pyrrophyta. The predominant genera were *Oedogonium, Stigeodonium* and *Spirogyra.* The maximum amounts of chlorophyll *a* were correlated with the dominance of filamentous forms and the low values were observed in poor samples which contained paucity of green or blue green algae. *Spirogyra* was recorded mainly in the southern part of the Lake (Abu Simbel and Tushka).

Fungi

25 identified and 4 unidentified species related to eleven genera of aquatic phycomycetes were recorded from surface water samples, collectd from Lake Nasser. The richest water samples in aquatic phycomycetes species were characterised by relatively low temperatures (15.9 - 20.3 °C) and pH range between 7.4 and 8.3. The poorest samples were characterised by relatively high temperatures (20.6 - 33.1°C), pH values fluctuating between 6.3 and 9.2, dissolved oxygen varying from 4.5 to 10.6 mg/l, total soluble salts ranging from 149 to 175 mg/l and the organic matter content between 2.0 and 51.1 mg/l. *Saprolegnia* and *Pythium* were the most frequent aquatic fungal genera; whereas *Aphanomyces, Dictyuchus, Pythiopsis, Leptomitus, Allomyces* and *Blastocladiopsis* were less frequent.

The fungal population of Lake Nasser showed marked vertical variations. High fungal counts were observed at the surface water mainly due to the high counts of *Aspergillus fumigatus* and *A. terreus.* Going deeper, the fungal population decreased till 30 m, then gradually increased to reach its maximum at 70 m depth. Such increase was basically due to the high population of *Penicillium funiculosum.*

Mesophilic fungi recoverd from the monthly samples of marginal water and submerged mud of Lake Nasser showed the highest fungal populations either in October, December 1985 or February 1986. Thermophilic and thermotolerant fungal species were common in one or more locality.

The richest submerged mud samples in aquatic fungi were characterised by somewhat alkaline pH, ranging between 7.1 and 7.9, by low amounts of total soluble salts (1.9-2.9 mg/100 g mud sample) and low organic matter (1.6-1.9 mg/100g). *Pythium* and *Saprolegnia* were the commonest aquatic fungal genera whereas *Leptomitus* and *Nowakowskiella* were less frequent.

Bacteria

Microbiological studies of Lake Nasser during 1974, 1984 and 1996 showed regional, seasonal and yearly variations. In 1974 and 1984 the lowest total bacterial counts (TBCs) at 22 and 37 °C were recorded in winter and maximum values in summer. There was a gradual decrease in TBCs from south to north with highest values near the HD. Furthermore, TBCs in 1984 were higher than in 1974, and those in 1996 were more than thousand fold those recorded in 1984. In 1996 total bacterial counts determined at 22 and 37 °C showed maximum values in spring at all sites in the main channel and khors (no data were recorded in summer), while minimum values were recorded in autumn. In khors the TBCs of surface waters recorded during winter were higher than those in the main channel. The ratio between total bacterial counts at 22 and 37 °C in Lake Nasser is more than one, with slight changes since its early filling, an indication that it is still unpolluted.

The counts of both asymbiotic-nitrogen fixers the aerobes *Azotobacter* and the anaerobes, N_2-fixing bacteria tended to decrease in 1984 compared to ten years earlier. This might be due to the drought and less suspended material reaching from the south, which carry these organisms in flood water.

The nitrifying bacteria showed a remarkable increase in 1984 compared with counts in 1974, associated with increase in nitrifying activity related to higher activity of the total bacterial load. This led to an increase in the nitrate content of the Lake water after the drought in 1984. An indication of eutrophication of Lake Nasser is the remarkable increase of pH in spring 1984 as compared to that in autumn 1974.

Four different genera with 8 species of purple non-sulfur bacteria were recorded from Lake Nasser. *Rhodopseudomonas,* the most common genus at all sites, was represented by 3 species: *R. acidophila, R. blastica* and *R. palustris. Rhodomicrobium* was the next in frequency, represented by *R. vannielli*, recorded only from khor sites. *Rhodocyclus* was represented by *R. gelatinosus* and *R. tenuis,* while *Rhodobacter,* and *Rodospirillium* each was represented by one species. It was observed that khor sites were richer in the number of isolates and genera of non-sulfur bacteria than the main body of Lake Nasser. Furthermore, purple non-sulfur bacteria in Lake Nasser exhibited seasonal and regional distribution.

Studies on the coliform and faecal coliform bacteria in the main channel showed that their number was highest in winter near the High Dam compared with other localities. In other sites the highest values were recorded also in winter (no records were undertaken in summer), while minimum values were found in autumn. The number of coliform and faecal coliform bacteria at the bottom of khors was higher than those at the surface. Furthermore certain Khors (Kalabsha and Korosko) were devoid of both types of bacteria.

Chapter 6
Zooplankton and Zoobenthos

ZOOPLANKTON

THE MAIN CHANNEL

Zooplankton organisms form an important link in aquatic food chains, since they are therefore secondary producers. It is necessary to study zooplankton in detail to elucidate the dominant species, their seasonal, horizontal and vertical distribution; and also the relationship among zooplankton distribution, chlorophyll *a* and transparency of water in the Lake. In other words, it is important to complete the general picture of the Lake productivity.

Species diversity. Many investigators studied the zooplankton of Lake Nasser and its khors since its early filling (Samaan 1971; Rzóska 1974; Samaan & Gaber 1976, 1981; Zaghloul 1985; Guerguess 1986a and b; Abdel-Mageed 1992, 1995; Mohamed, I. 1993k; Mohamed, M. 1993c and g; Iskaros 1993; Habib 1995b, 1996b, 1997 and 1998c; Shehata *et al.* 1998a and b; El-Shabrawy, 1998). Most of these studies were carried out for limited periods and localities. Studies on zooplankton in the main channel, which extended for four seasons, are those of Zaghloul (1985), Abdel-Mageed (1995), Shehata, S. *et al.* (1998a and b), even though based on the examination of a limited number of samples from various depths. However, such studies may give an idea about the diversity, density, standing crop and distribution of zooplankton in the Lake and its succession during various periods. The total number of species recorded in Lake Nasser by various investigators is 79 spp., belonging to four major groups: Protozoa (8 families and 10 spp.), Platyhelminthes (1 family and 1 sp.), Rotifera (16 families and 48 spp.) and Arthropoda (9 families and 21 spp.) (Table 65) in addition to minor groups of rare occurrence such as free living nematodes, chironomid larvae, fish eggs and larvae. Zaghloul (1985) recorded 28 species (4 protozoans, 10 rotifers, 9 copepods and 5 cladocerans). Abdel-Mageed (1992) working in Khor El-Ramla,

listed 36 species (26 rotifers, 7 cladocerans and 3 copepods). In his study at Khor Kalabsha, Iskaros (1993) recorded 42 species (29 rotifers, 7 cladocerans, 5 copepods and one species of ostracods). Abdel-Mageed (1995), in his study at 10 localities along the main channel during 1993 and 1994 listed 54 species (36 rotifers, 8 cladocerans, 3 copepods, 6 protozoans and one turbellarian species in addition to the minor groups (Table 65). The 36 rotifer species recorded by Abdel-Mageed (1995) and Shehata, S. *et al.* (1998a) belong to 20 genera and 16 families, the genera *Keratella* (72% of total rotifers) and *Brachionus* (18.53% of total rotifers) were dominant, constituting 90 % of the total rotifer number, a finding which agrees with that of previous authors (Zaghloul 1985, Abdel-Mageed 1992, Iskaros 1993). The highest number of zooplankton species was that of Rotifera (48 species out of 80 species – Table 65) which may be attributed to the high alkalinity of Lake Nasser which favours the occurrence of rotifers. Train (1979) pointed out that rotifers prefer alkaline waters. Thus Abdel-Mageed (1995) found a positive correlation between rotifers density and alkalinity.

The differences between species diversity, composition, density and standing crop, given by various authors may be attributed to differences in methodology, number of samples examined and inclusion or exclusion of littoral species. However, the species pattern of Lake Nasser recorded by various investigators, since its early filling gives a good indication of the dynamic balance of the communities as previously mentioned by MacLachlan (1974).

Density. The density of zooplankton in the Lake was studied by different authors (Samaan 1971, Samaan & Gaber 1977 and 1981, Ateato 1985, Zaghloul 1985, Abdel-Mageed 1995, Habib 1995b, 1997 and 1998c, El-Shabrawy, 1998). The results of these studies indicate that Lake Nasser is very rich in zooplankton (Table 66). It seems that figures given by these authors from 1979 to 1995 are comparable except for those of Ateato (1985) who gave higher figures (215,504 ind./m^3). However, figures as high as 733,99/ind./m^3 were recorded in autumn at Tushka at 0-10m depth (Abdel-Mageed 1995).

Studies by various investigators indicate that the zooplankton community of Lake Nasser is dominated by copepods, rotifers and cladocerans (Zaghloul 1985, Abdel-Mageed 1992, 1995, Iskaros 1993, Habib 1995b). Habib (1995b) studied the density and distribution of zooplankton at 6 localities in February 1994 and her results showed that copepods mainly nauplii are dominant (68.5%) followed by cladocerans (18.9%), and rotifers 12.8 % (Tables 67 and 68 and Fig. 88). In 1993/1994 Abdel-Mageed (1995) found that copepods (62.39%), rotifers (29.54%) and cladocerans (7.55%) constituted 99.48% of the total zooplankton of the Lake. The highest density of copepods was recorded in autumn (75, 312 ind./m^3) due to the dominance of larvae (53,695 ind/ .m^3) which feed mainly on phytoplankton

flourishing in autumn in the Lake (Abdel Monem 1995). The average number of rotifers was 22,219 ind./m^3 decreasing with increasing depth. Rotifers are dominant in spring when copepod density is low and the oxygen content is high and the temperature is low. Thus, the predation effect of most copepods on rotifers is low in spring (Hutchinson 1967). Furthermore, Galati (1978) pointed out that rotifers prefer cold water. In addition Abdel-Mageed (1995) found that rotifers in Lake Nasser were positively related to dissolved oxygen, thus confirming the observation of Herzig (1989) who pointed out that population development of rotifers is limited by the effect of oxygen concentration. Abdel-Mageed (1995) found that *Keratella cochlearis* density increased with increasing oxygen content.

***Table* 65 List of zooplankton species recorded from Lake Nasser by different authors. [Plates 9-13]**

Taxa and Species	1981	1989/90	1989/90	1993/94
	1 Zaghloul (1985)	2 Abdel-Mageed 1992	3 Iskaros 1993	4 Abdel-Mageed 1995
PROTOZOA				
Ciliophora				
Holophryidae				
Lacrymaria olor Müller, 1773*	-	-	-	+
Microregma auduboni Smith	+	-	-	-
Didniidae				
Acropisthium mutabile Perty, 1850*	-	-	-	+
Epistylidae				
Epistylis bimarginata Nenninger, 1880*	-	-	-	+
Euplotidae				
Euplotes patella Müller, 1786*	-	-	-	+
Tintinnidae				
Tintinnopsis cincta Claparéde & Lachmann	+	-	-	-
Strobilidiidae				
Strobilidium gyrans Stokes	+	-	-	-
Rhizopoda				
Sarcomastigophora				
Arcellidae				
Arcella discoides Ehrenberg, 1832*	-	-	-	+
Centropyxidae				
Centropyxis aculeata (Ehrenberg, 1882)*	-	-	-	+
PLATYHELMINITHES				
Turbellaria				
Dalyelliidae				
Microdalyellia sp. *	-	-	-	+

ROTIFERA (ROTATORIA)

Philodinidae				
Rotaria citrina (Ehrenberg, 1932)*	-	-	-	+
Brachionidae				
Brachionus patulus Müller, 1786	-	+	-	+
B. falcatus Zacharias, 1898	-	+	+	+
B. plicatilis (Müller, 1786)	-	+	-	+
B. calyciflorus (Pallas, 1766)	+	+	+	+
B. caudatus (Barrois & Daday, 1894)	+	+	+	+
B.angularis (Gosse, 1851)	+	+	+	+
Keratella cochlearis (Gosse, 1851)	+	+	+	+
K. procurva (Thorpe, 1891)	-	+	-	+
K. tropica (Apstein, 1907)	+	+	+	+
K. quadrata Müller, 1786	-	-	+	-
Anuraeopsis fissa (Gosse, 1851)	-	+	+	+
Platyias patulus Müller, 1788	-	+	+	-
Euchlanidae				
Euchlanis dilatata (Ehrenberg, 1832)	-	+	+	+
Collurellidae				
Lepadella patella (Müller, 1773)	-	+	+	+
L. ovalis (Müller, 1786)	-	-	+	+
Colurella adriatica (Carlin, 1939)	-	+	-	-
C. obtusa (Gosse, 1851)	-	-	+	-
Lecanidae				
Lecane luna (Müller, 1776)	+	+	+	+
L. depressa (Bryce, 1891)	-	-	+	+
Monostyla elachis (Harring & Mers, 1913)*	-	-	-	+
M. bulla (Gosse, 1886)	+	+	+	+
M. lunaris (Ehrenberg, 1882)	-	-	-	+
M. closterocerca Schmarda	-	-	+	-
Notommatidae				
Cephalobdella catellina (Müller, 1786)	-	+	+	+
Scaridium longicaudum (Müller, 1786)	-	+	+	-
Trichocercidae				
Trichocerca similis (Wierzejski, 1893)	-	+	-	+
T. longiseta **Schrank**	+	-	+	-
T. chattoni (Beauchamp, 1907)*	-	-	-	+
T. collaris (Rousselet, 1892)*	-	-	-	+
T. pusilla (Lauterbon, 1898)*	-	-	-	+
T. porcellus Gosse, 1851	-	-	+	-
T. stylata (Gosse, 1851)*	-	-	-	+
Trichotria tetractis (Ehrenberg, 1843)	-	+	-	-
Synchaetidae				
Polyarthra vulgaris (Carlin, 1943)	-	+	-	+
Polyarthra sp.	-	-	+	-

Asplanchnidae				
Asplanchna priodonta (Gosse, 1861)	+	+	+	+
Dicranophoridae				
Pedipartia sp.*	-	-	-	+
Gastropodidae				
Ascomorpha ecaudis (Perty, 1850)*	-	-	-	+
Collothecidae				
Collotheca balatonica (Varga, 1936*)*	-	-	+	+
Testudinellidae				
Testudinella patina (Hermann, 1783)	-	-	+	+
Pompholyx complanata (Gosse, 1851)	-	-	+	+
Conochilidae				
Conochilus hippocrepis (Schank, 1830)	-	-	+	+
Conochiloides sp.	-	-	+	-
Hexarthridae				
Hexarthra mira (Hudson, 1871)	-	+	+	+
Polyarthra vulgaris Carlin	-	+	-	-
Filiniidae				
Filina longiseta *(*Ehrenberg, 1834*)*	+	+	+	+
F. opoliensis (Zaocharias, 1898)	-	+	+	+
ARTHROPODA				
Crustacea				
Branchipoda				
Cladocera				
Sididae	+	+	+	+
Diaphanosoma excisum Sars, 1855				
Daphnidae				
Daphnia longispina Müller, 1785	-	-	-	+
D. barbata Weltner, 1898	+	+	+	-
Ceriodaphnia cornuta Sars, 1885	+	+	+	+
Bosminidae				
Bosmina longirostris *(*Müller, 1776*)*	+	+	+	+
Macrothricidae				
Macrothrix spinosa King, 1853	-	+	-	+
ıyidoridae				
Alona intermedia Sars, 1862	-	+	-	+
A. affinis Leydig	+	-	+	-
A. quadrangularis *(*Müller, 1785)	-	+	-	+
Chydorus sphaericus (Müller, 1776)	-	-	+	+
Maxillopoda				
Copepoda				
Cyclopoida	+	+	+	+
Thermocyclops hyalinus (Ehrenberg, 1880)	+	+	+	+
Mesocyclops leuckarti (Claus, 1857)	+	-	-	-
Cyclops vernalis Fischer	+	-	-	-

Acanthocyclops americanus Marsh	+	-	-	-
Halicyclops magniceps Lilljeborg				
Ergasilidae				
Ergasilus sieboldi Nordmann	+	-	+	-
Calanoida				
Diaptomidae				
Thermodiaptomus galebi (Barrois, 1891)	-	+	+	+
Diaptomus wierzejskii Richard	+	-	-	-
D. minutus Lilljeborg	+	-	-	-
D. marshianus M.S.Wilson	+	-	-	-
Ostracoda				
Cypris sp.	-	-	+	-
34 Families	**27**	**36**	**42**	**54**

(1) Zaghloul 1985 (main channel), (2) Abdel-Mageed 1992 (Khor El Ramla), (3) Iskaros 1993 (Khor Kalabsha), (4) Abdel-Mageed 1995 (Main channel). * Recorded for the first time in Lake Nasser.

Cladocera attain their maximum abundance in summer due to the flourishing of *Diaphanosoma excisum* and *Ceriodaphnia cornauta* which prefer warm water (Abdel-Mageed 1995). The latter author recorded the highest zooplankton density (733,991 ind./m^3) during 1993/1994 at Tushka in autumn at 0 - 10 m depth, and the minimum (5,500 ind./m^3) at the surface water near the High Dam in spring.

Lake Nasser is very rich in zooplankton. Habib (1995b) recorded the maximum number (562,100 ind./m^3) at 5-m depth at Abu Simbel in February, 1994 (Table 62). It is clear that the southern region of the Lake is richer in zooplankton than the northern. The total number of zooplankton at Korosko, Tushka, and Abu Simbel were 294,800; 233,900 and 562,900 ind. /m^3 respectively, while at El Ramla, Kalabsha and Allaqi, the average total numbers were only 52,900, 156,400 and 154,800 ind. /m^3 respectively (Table 67). The vertical distribution of zooplankton in Lake Nasser shows that at Abu Simbel high numbers of zooplankton were recorded at all depths (Table 68).

Samaan (1971) estimated the zooplankton standing crop in the upper 10 meters during March 1970 from three localities, viz., El-Ramla, El-Madiq and Khor Singari, which amounted to 21,807, 20,037 and 45,534 ind./m^3 respectively (Table 69). The results suggest that khors are richer in zooplankton, being nearly twice as from the main channel (Table 69). The latter author pointed out that near the southern end of the Lake colonies of *Volvox* spp., Cladocera (mainly *Daphnia* spp.) and Copepoda (mainly *Cyclops* spp.) formed numerically 49.1, 34.2 and 16.7% respectively; while in the northern part of the Lake Cladocera and Copepoda constituted 57.1 and 42.9% respectively. In the middle third of the Lake the picture was different, as

Cladocera, Copepoda and *Volvox*[*] spp. comprised numerically 42.6, 43.6 and 13.8% respectively. So, it seems that species density and diversity differ from one locality to another. At the early stage of filling of Lake Nasser very dense populations of *Volvox*[*] colonies appeared in the plankton, later in Lake Nubia, but these flagellates almost disappeared in 1974 (Entz, 1980b). A similar aspect on the development of *Volvox* could be observed often in other African lakes (e.g. Lake Volta, Beadle, 1974). However, *Volvox globator* is still occurring in the Lake as it is recorded by Zaghloul (1985), and in the southern region of the Lake in 1990 by Mohamed, I. (1993j) (Fig. 92).

Table 66 **Average annual density of zooplankton in Lake Nasser.**

	Average density of zooplankton (ind./m^3)	Author	
Northern and Southern regions			
	43,593	Samaan and Gaber	(1976)
	79,925	Gaber	(1981)
	84,660	Zaghloul	(1985)
	215,504	Ateato	(1985)
	66,000	Mohamed, I.	(1993j)
	75,224	Abdel-Mageed	(1995)
Northern region			
	52,900 - 156,400	Habib	(1995b)
Southern region			
	233,900 - 562,100	Habib	(1995b)

Seasonal distribution. Bowers (1979) and Moss (1980) pointed out that zooplankton density does not always correlate with phytoplankton; it depends mainly on the species diversity of phytoplankton. In 1976, zooplankton were more abundant in March than in August (Fig. 89, Latif 1984a). In March, zooplankton were more abundant in the region from El-Madiq to Tushka; while Adindan showed the lowest values. In August, the northern region had values less than those from the southern region. Tushka and Abu Simbel showed the maximum values, while at Adindan zooplankton were much less abundant (Fig. 89). Copepods, particularly their nauplii, are the most dominant groups, followed by Cladocera and Rotifera.

In April 1986, Mohamed, M. (1993c) studied the distribution of zooplankton at six stations along the main channel and his results (Fig. 90) showed that Copepda were the most dominant group, forming numerically 70.4%, followed by Cladocera (25.5%), and Rotifera which were rarely (4.1%) recorded. *Diaptomus* spp. were an important constituent of zooplankton as they formed numerically 43%, followed by *Cyclops* sp. and *Daphnia* sp. (16 and 15% respectively) (Fig. 89). *Asplanchna* sp. was the main rotifer species in the 6 stations (2.5%). It seems that zooplankton population is rich in number of individuals, although represented by few species only (Fig. 92).

[*] *Volvox globator* is classified by some authors (Soliman 1996) with Protozoa as a member of Phylum Sarcomastigophora (Class Phytomastigophora, Order Volvocida). Other authors (Zaghloul 1985), however include it with phytoplankton (Class: Chlorophyceae order Volvocales)

Table 67 **Distribution of zooplankton and percent of the different groups to 20 m depth during February 1994 (Habib 1995b).**

Location	Cladocera (ind./l)	%	Copepoda (ind./l)	%	Rotifera (ind./l)	%	Total zooplankton (ind./l)
Northern region							
El Ramla	9.6	18.3	40.8	77.6	2.5	4.8	52.9
Kalabsha	38.0	24.3	107.4	68.7	11.0	7.0	156.4
Allaqi	33.5	21.9	110.9	71.6	10.4	6.7	154.8
Southern region							
Korosko	55.8	18.9	226.7	76.9	12.3	4.2	294.8
Tushka	30.1	12.9	153.3	65.5	50.5	21.6	233.9
Abu Simbel	96.3	17.1	283.9	50.5	181.9	32.4	562.1
Average	43.9	18.9	153.8	68.5	44.7	12.8	242.4

[For stations refer to Fig. 4].

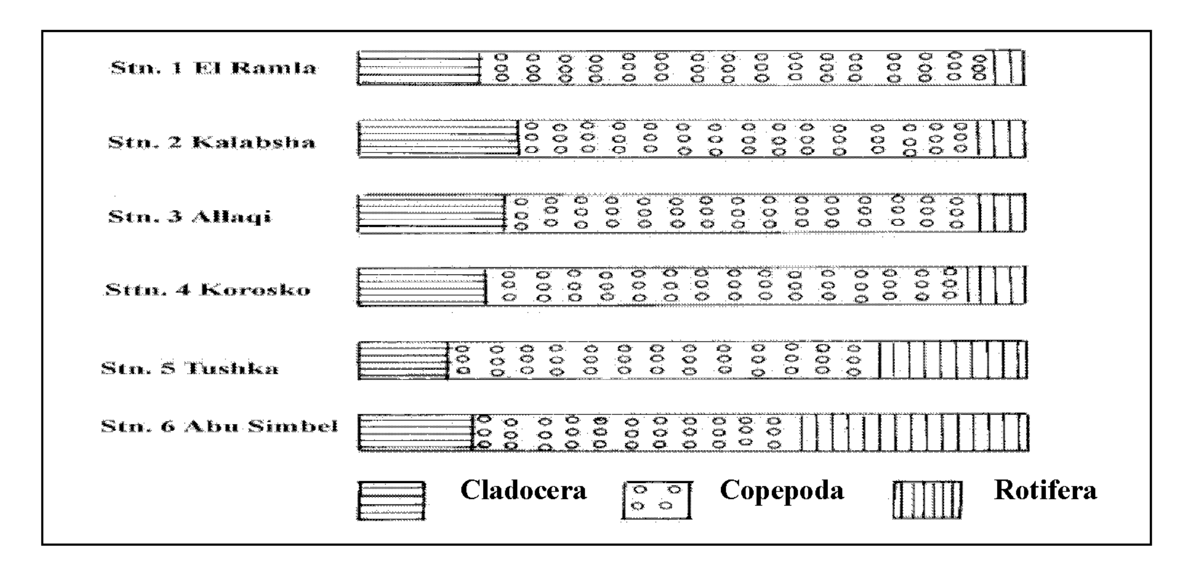


Fig. 88 **Percentage of zooplankton groups in Lake Nasser (Habib 1995b) [**For stations refer to Fig. 4**].**

Table 68 **Vertical distribution of zooplankton (ind./l) at various depths at six stations along the main channel of Lake Nasser (Habib 1995b).**

Location	0	5	10	15	20 (m)
Northern region					
El-Ramla	9.6	15.6	14.4	10.9	2.1
Kalabsha	19.2	29.7	28.3	34.6	44.6
Allaqi	8.7	54.9	40.8	26.7	23.7
Southern region					
Korosko	72.9	90.9	66.0	33.1	31.9
Tushka	41.0	64.8	50.5	36.5	41.1
Abu Simbel	120.2	135.8	96.1	75.2	134.8

[For stations refer to Fig. 4].

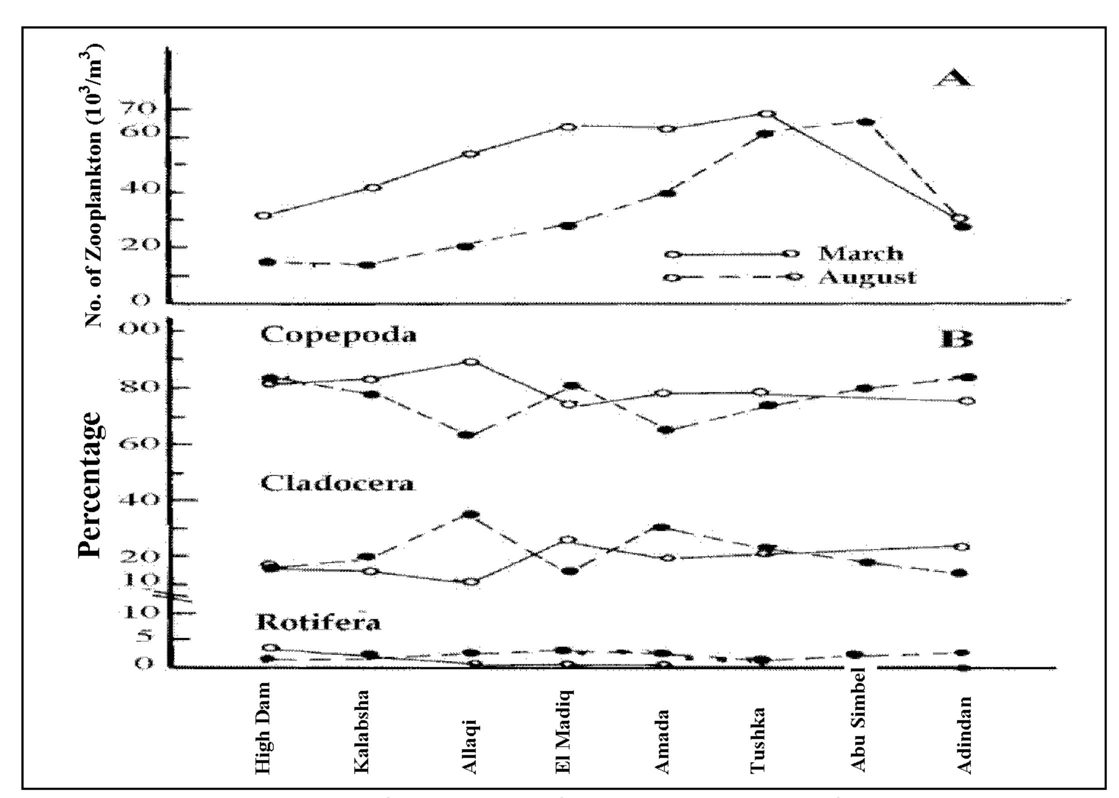


Fig. 89 **Zooplankton at different stations along the main channel of Lake Nasser in March and August 1967 A: number of zooplankton ($10^3/m^3$), B: percentage of Copepoda, Cladocera and Rotifera (Latif 1984b).**

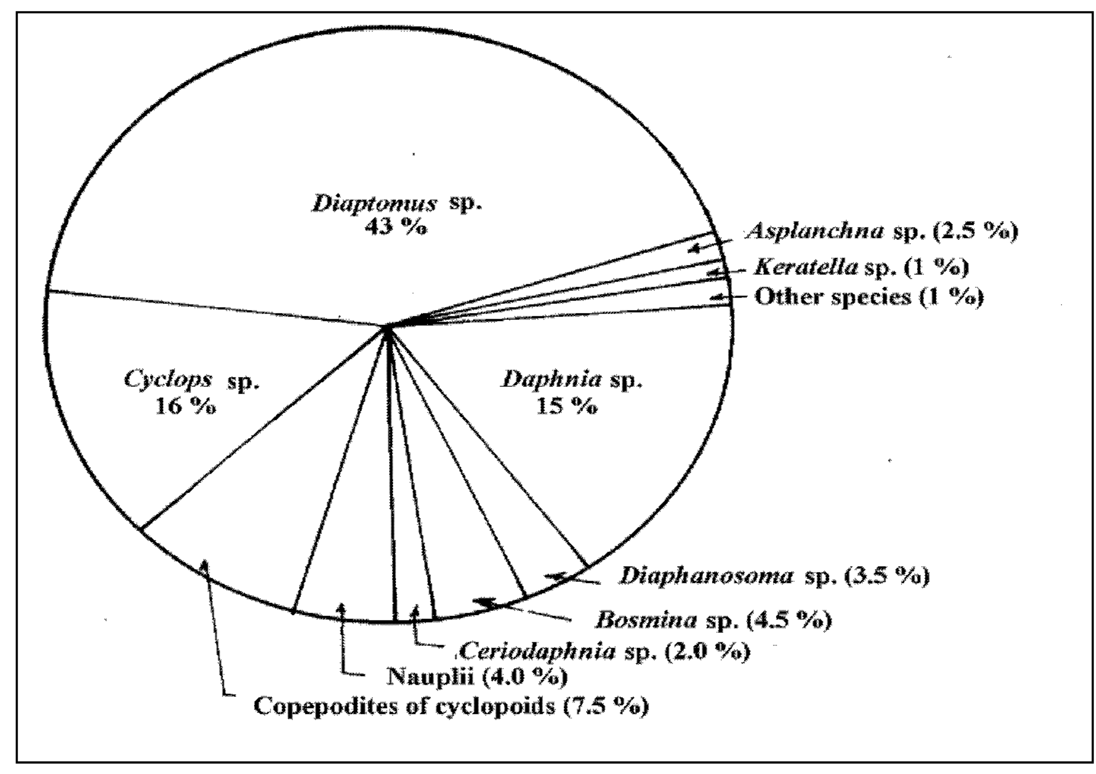


Fig. 90 **Percentage of zooplankton species in Lake Nasser recorded in April 1986 (Mohamed, M. 1993c).**

Table 69 **Number of zooplankton (ind./m^3) at different localities of Lake Nasser (Samaan 1971).**

Zooplankton	Locality		
	El Ramla	El-Madiq	Khor Singari
Copepoda			
Calanoida	510	3150	900
Cyclopoida	8850	8151	11490
Copepod nauplii	8349	7449	23499
Cladocera			
Sida sp.	549	798	7800
Bosmina sp.	449	300	898
Daphnia sp.	---	---	150
Rotifera			
Keratella sp.	2100	2790	699
Brachionus sp.	600	399	198
Standing Crop (ind./m^3)	21,807	20,307	45,534

Abdel-Mageed (1995) studied the seasonal variation of zooplankton during 1993/94 at 10 stations along the main channel and found that the flood water period (autumn) was marked by very high population density (average, 99,803 ind./m^3) due to the increase of copepods. The remaining seasons exhibited a variety of overlapping patterns, showing no statistically significant difference. Lower densities were recorded in winter, spring and summer being 68,899, 68,816 and 63,318 ind./m^3 respectively. The seasonality of zooplankton showed variable patterns at each station.

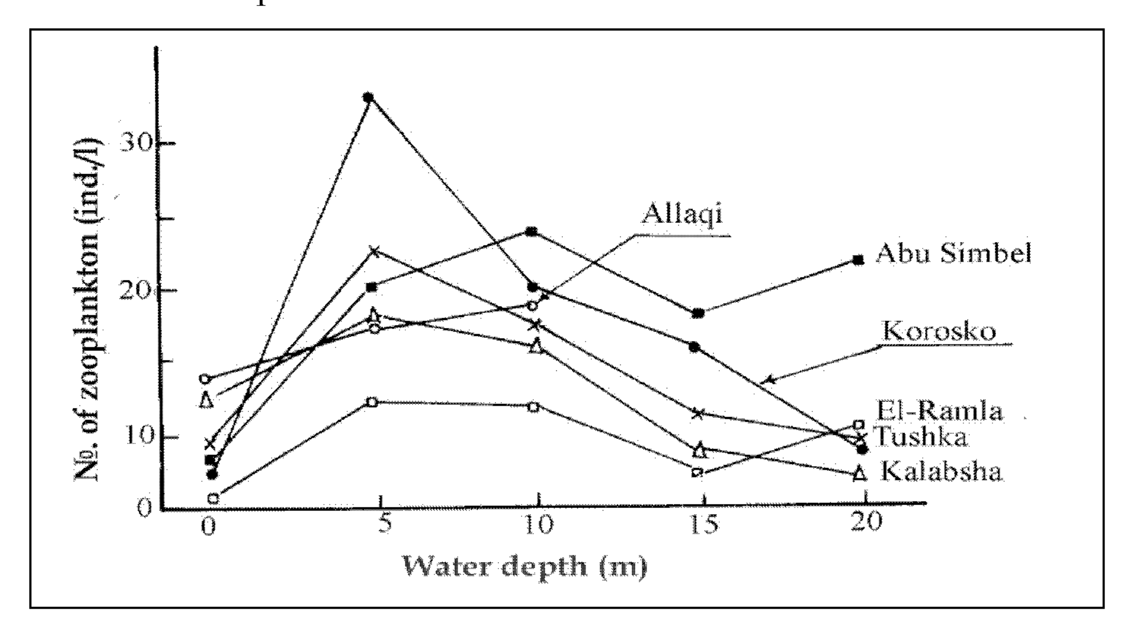


Fig. 91 **Vertical distribution of zooplankton in Lake Nasser (Mohamed, M. 1993c).**

□ **El Ramla (Stn.1)**	△ **Kalabsha (Stn. 2)**
o **Allaqi (Stn. 3)**	● **Korosko (Stn. 4)**
x **Tushka (Stn. 5)**	■ **Abu Simbel (Stn. 6)**

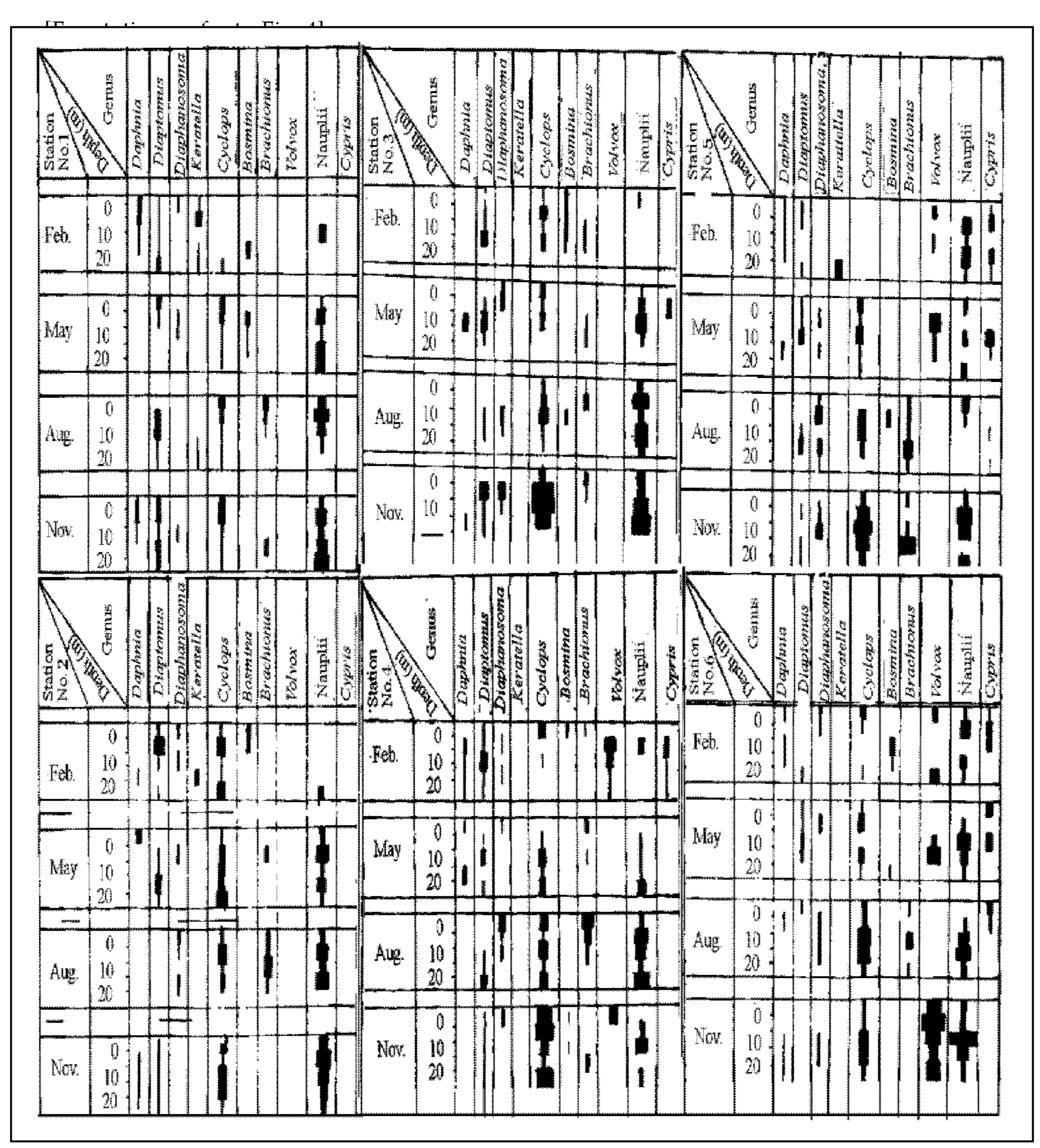


***Fig.* 92 Seasonal variations of vertical distribution of zooplankton at stations 1-6 along the main channel of Lake Nasser in 1990 (Mohamed, I. 1993j). Scale bar = 10 ind. / ml** [For stations refer to Fig. 4].

Vertical and monthly distribution. The vertical distribution shows that the zooplankton were much more abundant at 5 and 10 m depth compared with other depths (Fig. 90). The relationship among the number of zooplankton per litre, mean value of chlorophyll *a* (mg/m^3) and transparency indicate that the highest mean value of chlorophyll *a* concentration was 9.1 mg/m^3 at station 4 (Korsoko) and the lowest one was 2.9 mg/m^3 at station 1 (El Ramla) (Fig. 96).

In 1990, Mohamed, I. (1993j) studied the seasonal variations of vertical distribution of zooplankton at 6 localities in the main channel of Lake Nasser, his results are shown in Fig. 92. The results indicated that in February 1990 the

highest values were recorded for nauplii at stations 5, 6; for *Volvox* spp. at stations 4, 6; for *Cyclops* spp. at stations 2, 3; for *Diaptomus* spp. at stations 2, 3 and 4; for *Bosmina* spp. at stations 2 and 3; for *Keratella* spp. at station 1 and for *Daphnia* spp. at stations 1, 4 and 5 (Fig. 93). In May 1990, the highest values for nauplii, *Volvox* spp., *Cyclops* spp., *Diaptomus* spp., *Diaphanosoma* and *Daphnia* spp. were recorded at stations 1-4 and 6; 2, 1, 4, 5, 6; 6, 4, 2; 3 and 2, 3, 4 (Fig. 93). In August 1990, the highest values of nauplii were recorded in all stations, *Cyclops* spp. at stations 6, 3 and 4; *Brachionus* spp. at stations 4, 5 and 2; *Diaphanosoma* spp. at stations 5 and 4; *Diaptomus* spp. at St. 1 (Fig. 93). In November 1990, the highest values of nauplii were recorded in all stations, *Cyclops* spp. at stations 3, 4 and 5; *Diaptomus* spp. at stations 1, 2, 3 and 4 and *Daphnia* spp. at stations 1 and 2 (Fig. 94).

Thus, zooplankton organisms were abundant in August and relatively poor in February and May. *Cyclops* spp. and nauplii were the main components of zooplankton in August and November throughout the main channel of Lake Nasser. *Diaptomus* spp. were distributed throughout the Lake in February and May, however their numbers were not high. *Keratella* spp. and *Cypris* spp. were not found in all stations in May and November, and *Volvox* spp. were not recorded in August (Mohamed, I. 1993j). The results indicate that zooplankton organisms were more abundant in the southern 3 stations than in the northern 3 stations. *Cypris* spp. and *Volvox* spp. , were recorded only in the southern region (Mohamed, I. 1993j).

Abdel-Mageed (1995) studied the seasonal and vertical distribution of zooplankton at depths from surface to 20 m during 1993/1994. The statistical analysis for zooplankton densities at various depths showed high significant differences with higher densities at 0 m and 0-10 m depth (average 31,943 ind./m^3) and decreasing densities with increasing depth. The annual average number recorded was 75,224 ind./m^3 which decreased with increasing depth, being 119,768, 73,962 and 31, 943 ind./m^3 at 0, 0-10 and 10-20 m depth respectively. This may be attributed to the richness of the upper water layers of Lake Nasser (till about 8 m) with phytoplankton, bacteria and detritus (Habib & Aruga 1988) which constitute the main food items of zooplankton. The high densities of zooplankton organisms recorded in the middle and southern regions of the Lake (Abdel-Mageed 1995) were parallel with the rich phytoplankton densities recorded in the same regions during the same period (Abdel-Monem 1995).

Habib (1995b) investigated the vertical distribution of zooplankton at 6 stations along the main channel of Lake Nasser in February 1994 (Table 68 and Fig. 95). It is obvious that the number of zooplankton organisms was much higher at 5 m depth, than at other depths in almost all stations, except at Abu Simbel where the maximum number of organisms was observed at 20 m depth

(Fig. 95). It is noteworthy that the southern region of the Lake, particularly Abu Simbel station, is very rich in zooplankton at all depths (Table 68 and Fig. 95). The relationships between zooplankton distribution, chlorophyll *a* concentration and transparency along the main channel of Lake Nasser and at all 6 stations, are illustrated in Fig. 96 (Mohamed, M. 1993c). It is obvious that there is a high correlation between the number of zooplankton individuals/l and the concentration of chlorophyll *a* (Fig. 96).

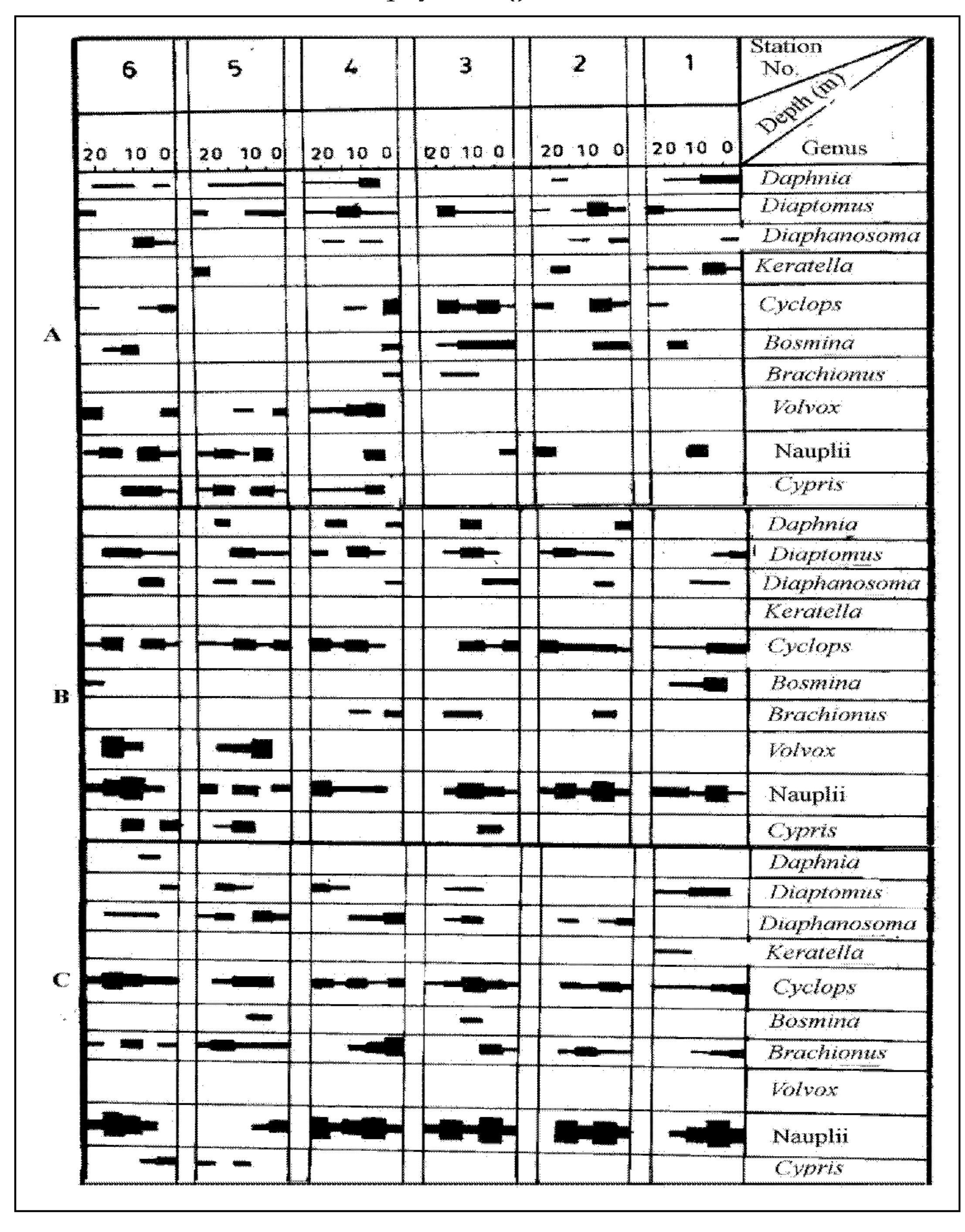


Fig. 93 **Vertical distribution of zooplankton in the main channel of Lake Nasser during A: February, B: May and C: August 1990 (Mohamed, I. 1993j). Scale bar 10 individuals/ml [**For stations refer to Fig. 4**].**

Fig. 94 **Vertical distribution of zooplankton in the main channel of Lake Nasser in November 1990 (Mohamed, I. 1993j) Scale bar = 10 individuals/ ml.** [For stations refer to Fig. 4].

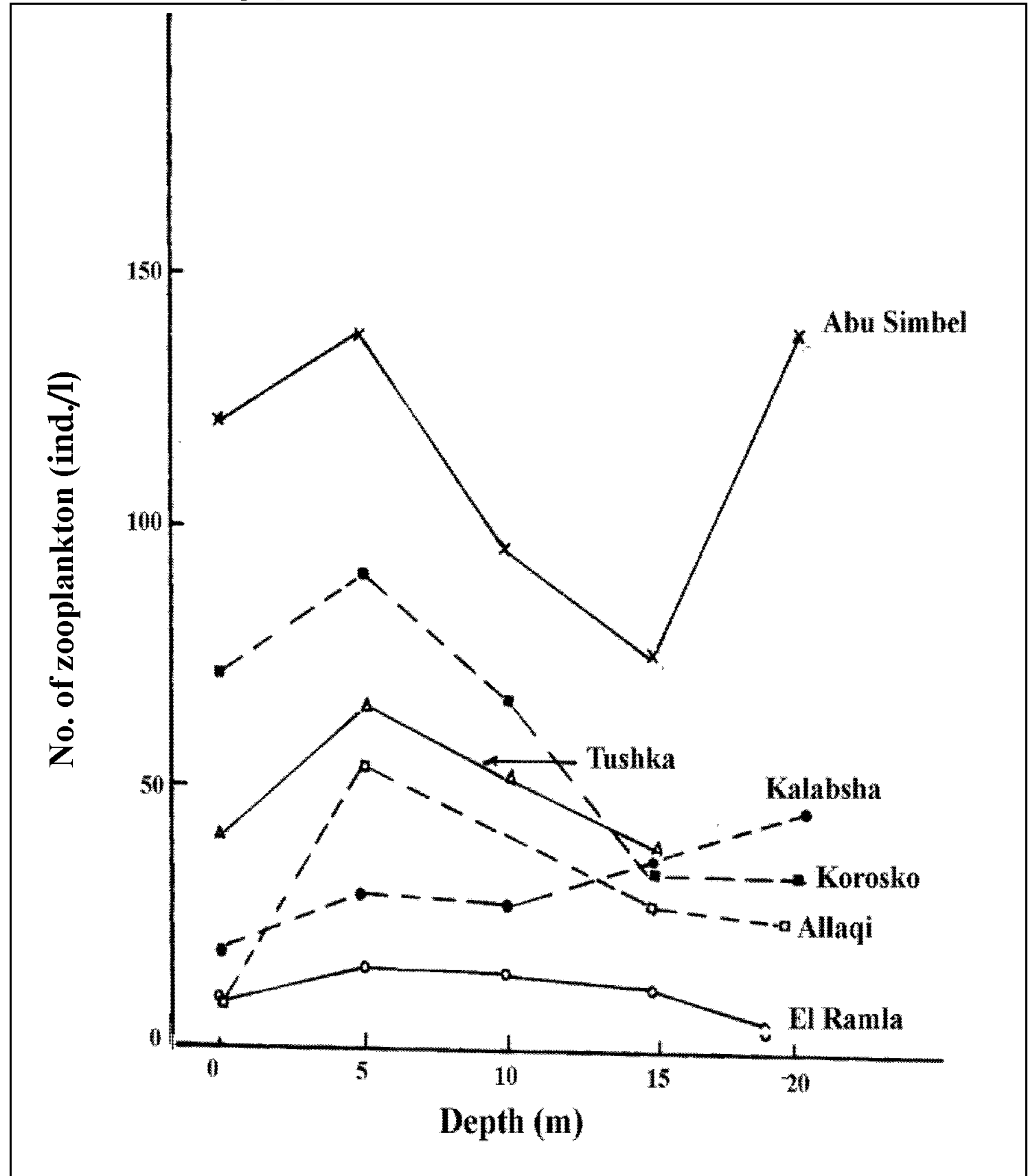


Fig. 95 **Vertical distribution of zooplankton in Lake Nasser (Habib 1995b).** [For stations refer to Fig. 4].

Table 70 **Regional and seasonal changes of zooplankton biomass (mg/m³) in Lake Nasser (July-December, 1990) [Mohamed, M. 1993g]**

Weight (mg/m³)	Region	Season

	Northern Stns. 1,2 and 3	Southern Stns. 4, 5 and 6	Hot season (July - Sept)	Cold season (Dec. - Jan.)
Wet	50 - 980	210 - 1940	50 - 480	190 - 1940
Dry	11 - 148	28 - 196	11 - 69	24 - 196

[For stations refer to Fig. 4]

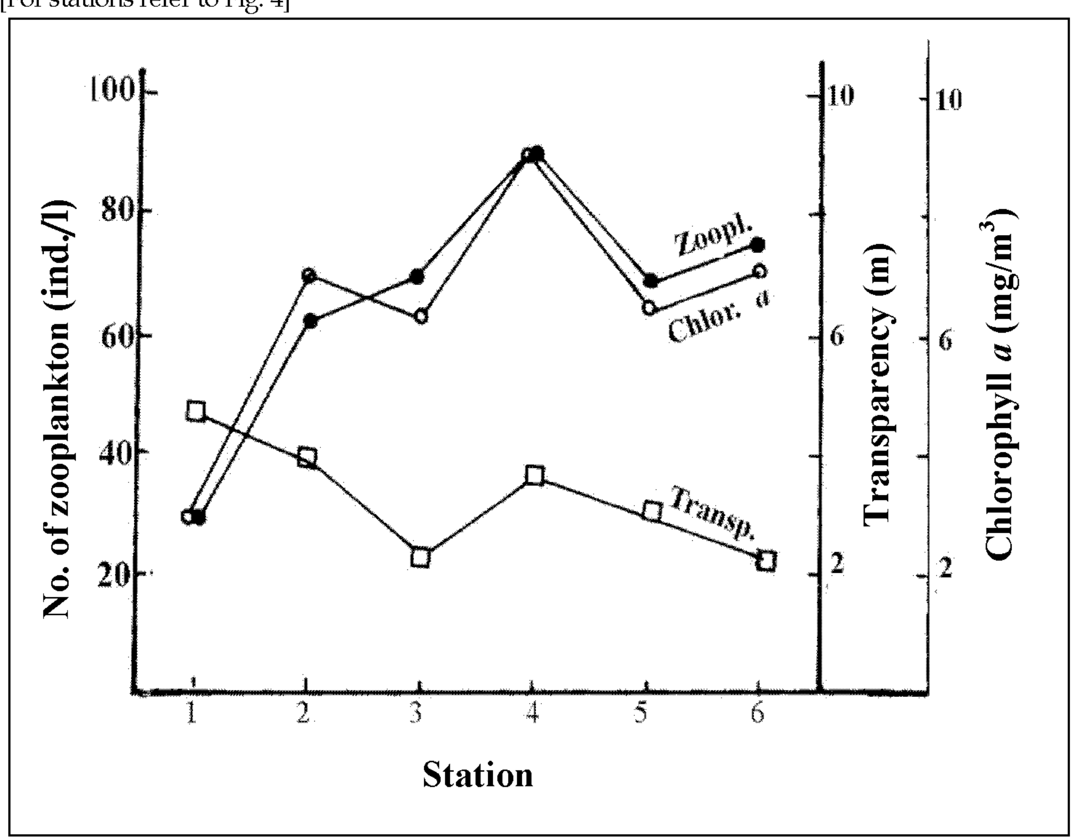


Fig. 96 **Relationship between zooplankton distribution (•), chlorophyll *a* (○) and transparency (□) at 6 stations in Lake Nasser (Mohamed, M. 1993c)** [For stations refer to Fig. 4].

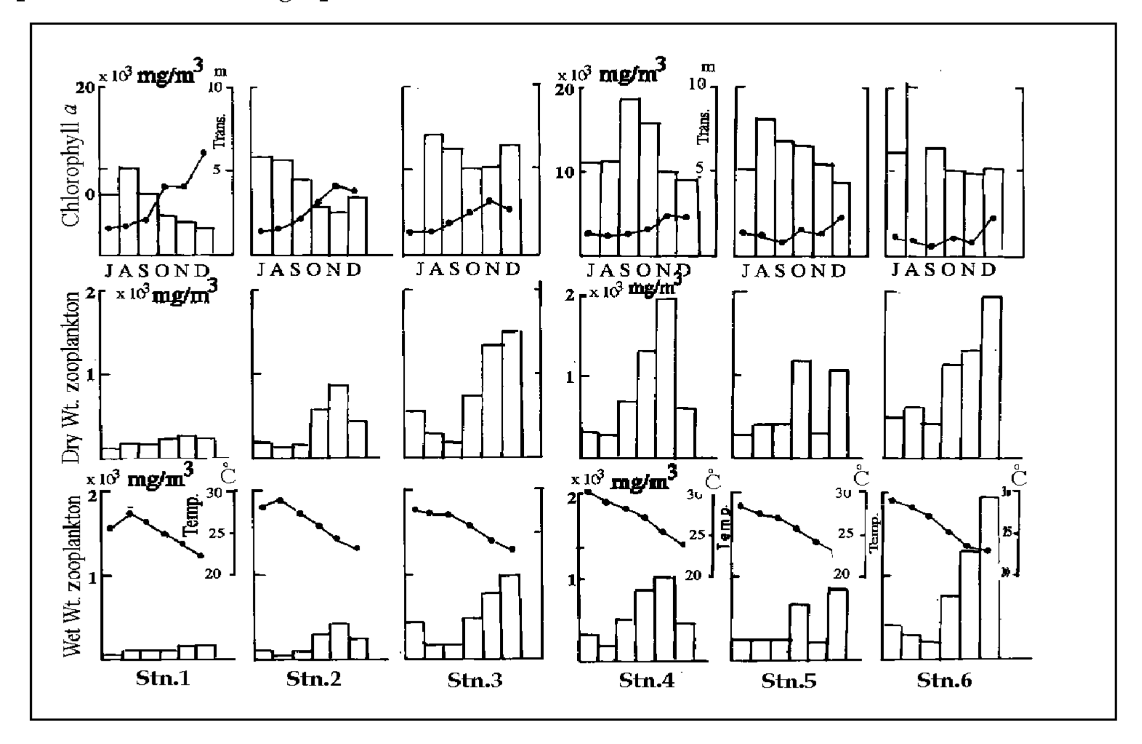


Fig. 97 **Monthly changes of transparency, water temperature, chlorophyll *a* concentration and wet and dry weights of zooplankton in the main channel at stations 1-6 (Mohamed, M. 1993g) [**For stations refer to Fig. 4**].**

Biomass. The horizontal distribution of zooplankton biomass along the main channel was studied in 1991 and 1990 by Mohamed, M. (1992, 1993g) [Tables 71 and Fig. 97]. The highest values (wet and dry weight) were recorded from the southern region (Stn. 5) in January, while the lowest values were recorded at stations 1 and 2 in the northern region during the hot season. The monthly changes of transparency, water temperature, chlorophyll *a* concentration, wet and dry weights at stations 1-6 from July to December 1990 (Fig. 97) indicate that:

1. The southern region is richer in zooplankton than the northern region which may be attributed to the high productivity of phytoplankton being the essential food for zooplankton.

2. High zooplankton density was recorded during the cold season, low density during the hot season (Tables 70 and 71).

3. At station 3 both wet and dry weights showed, more or less, a stable state, which may be due to that this station (Allaqi) is located in a shallow intermediate region between the southern and northern regions.

Table 71 **Distribution of total biomass of zooplankton (mg/m^3) during January to June 1991 at different localities of the main channel of Lake Nasser (Mohamed, M. 1992).**

Site	Jan.		Feb.		March		April		May		June	
	W.W*	D.W**	W.W*	D.W**	W.W*	D.W**	W.W*	D.W**	W.W*	D.W**	W.W*	D.W**
El Ramla 1	180	21.4	80	12.1	90	13.9	120	20.6	300	49.7	160	10.3
Kalabsha 2	170	21.0	190	24.5	510	52.9	160	27.0	220	30.9	120	6.1
Allaqi 3	250	41.5	320	40.3	630	65.6	280	58.4	680	75.6	520	40.1
Korosko 4	770	118.6	960	140.5	430	49.3	240	31.3	410	49.0	330	22.7
Tushka 5	1500	240.8	430	81.6	350	45.3	270	30.6	480	33.7	590	36.0
Abu Simbel 6	570	52.9	610	85.5	460	56.0	310	52.0	390	35.3	750	47.9

[For stations refer to Fig. 4] * Wet weight, ** Dry weight.

THE KHORS

Species diversity. Iskaros (1993) investigated the distribution and seasonal variation of zooplankton in Khor Kalabsha in relation to the dominant prevailing environmental conditions. The latter author identified 40 species belonging to Copepoda, Cladocera and Rotifera, and estimated the average annual density of zooplankton in Khor Kalabsha as 71,245 ind./m^3 during October 1989 to September 1990. It seems that zooplankton population is rich in the number of individuals in the Khor, but is represented by 11 genera.

Distribution. Abdel-Mageed (1992) studied the zooplankton at Khor El Ramla, and pointed out that the littoral zone of the khor has a sustainable standing stock of zooplankton all the year round with a minimum in summer and a maximum in winter (Table 72).

***Table** 72* **Seasonal variations of the standing stock of zooplankton in Khor El Ramla (Abdel-Mageed 1992).**

Zooplankton Standing stock (ind./m^3)	Summer	Autumn	Winter	Spring
	84,765	128,782	157,439	154,521

The overall picture of littoral zooplankton indicates that zooplankton density is minimum in summer (84,765 ind./m^3) increases in autumn with an average of 128,782 ind. /m^3, and almost get doubled in winter and spring with an average of 157,439 and 154,521 ind./m^3 respectively. It is worth mentioning that the highest standing stock is recorded from the depth of 5 m, with an annual average of 85,537 ind./m,^{3} the lowest density from the depth of 20 m, being 15,294 ind. /m^3.

Habib (1996b) studied the distribution and density of zooplankton at 5 stations to 10 m depth at Khor El Ramla in February, 1994 (Figs. 98 and 99) and found that Cladocera, Copepoda and Rotifera are the major zooplankton with an average percentage of 21.6 (15.3- 33.4); 33.6 (12.8-41.8) and 44.8% (24.8-71.9%) (Table 73). Copepods are the most dominant group at 2 stations followed by rotifers and cladocerans at one station. For the other stations, rotifers dominated other groups. The vertical distribution of zooplankton shows that zooplankton were most abundant at 10 m depth, except at stations 3 and 5.

***Table** 73* **Average density of zooplankton and percentage of different groups to 10 m depth during February 1994 in Khor El Ramla (Habib 1996b).**

Group	Ind./l	Percentage %

Rotifera	192.1	44.8
Copepoda	101.1	33.6
Cladocera	66.8	21.6
Total	360.0	100

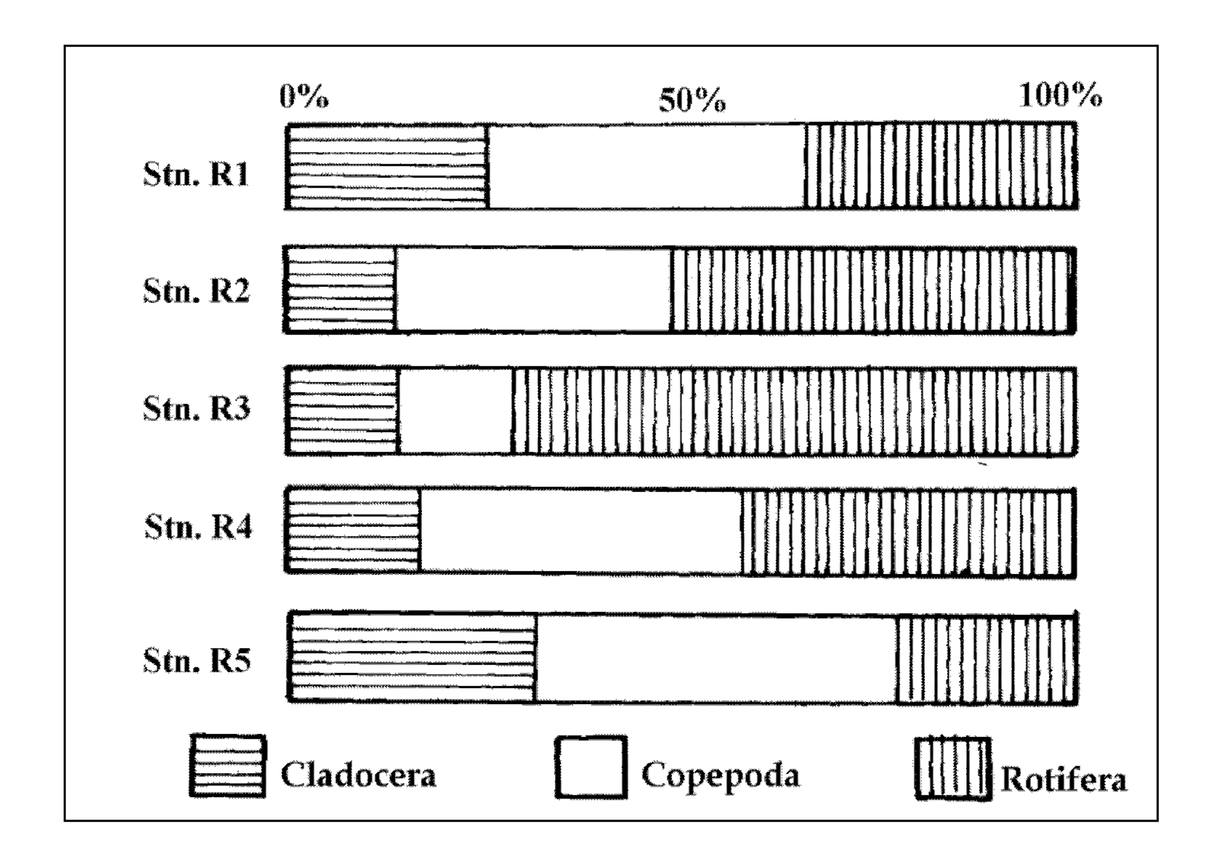


Fig. 98 Percentage of zooplankton groups in Khor El Ramla (Habib 1996b).

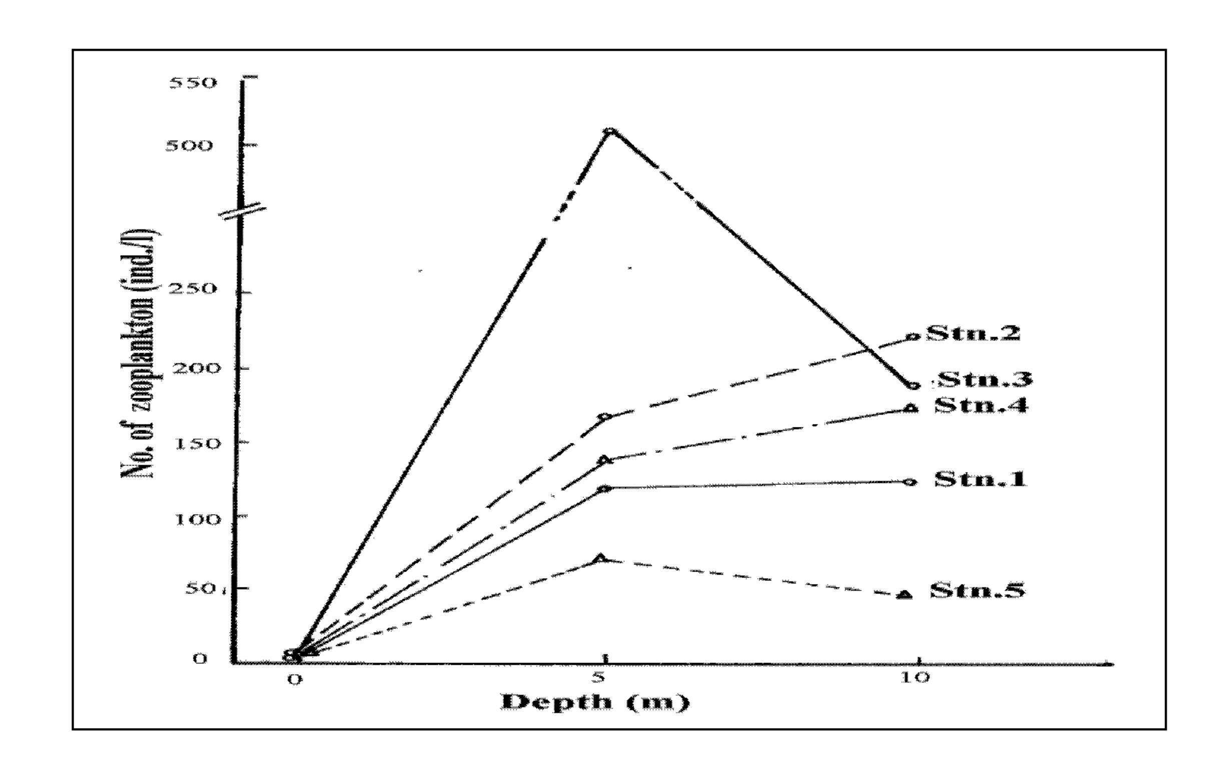


Fig. 99 **Vertical distribution of zooplankton in Khor El Ramla (Habib 1996b) [**For stations refer to Fig. 81**].**

ZOOBENTHOS

The different groups of benthos serve as an important food for various fish species in Lake Nasser (Latif 1974a; Iskaros 1988, 1993). These authors found that chironomid larvae form the major food items for *Mormyrus kannume*, *M. caschive* and *Chrysichthys auratus* throughout the different seasons. *Synodontis schall* and *S. serratus* feed mainly on gastropods, *Bulinus truncatus* and *Physa acuta*. Furthermore, they report that nymphs of Odonata and Ephemeroptera, larvae of Trichoptera, Corixidae are also infrequently recorded in the guts of the above 5 fish species. *Hydrocynus* spp., particularly *H. forskalii*, subsist mainly on insect larvae in winter (Iskaros 1993).

Species diversity. The first survey on bottom fauna in Lake Nasser was carried out by Entz (1978), who mentioned a gradual change in the components of benthos with the development of the Lake, particularly molluscs and oligochaetes. Latif *et al.* (1979) studied the distribution of benthic fauna of both Lake Nasser and Lake Nubia (only in the main channel) in March and July 1979 respectively and found that the major components of benthic fauna in Lake Nasser were the oligochaetes, while that of Lake Nubia were composed mainly of molluscs. Elewa (1987b) recorded 14 species. Detailed investigations were carried out by Iskaros (1988, 1993) on the distribution and seasonal variations of benthic organisms in Lake Nasser and adjacent waters (Aswan Reservoir and the River Nile) in relation to the prevailing environmental conditions and identified 40 species related to the aquatic Insecta, Mollusca, Annelida and Platyhelminthes. Fishar (1995) recorded 39 species of zoobenthos, 19 species previously recorded by Iskaros (1993) were not included in Fishar's (1995) list, and recorded 14 species for the first time (Table 74). In a survey of zoobenthos during 1996 (SECSF, 1996) only 19 species were recorded, which were previously known by other investigators. The total number of benthic invertebrate species recorded in Lake Nasser by various investigators is 59 species belonging to 4 major groups: Cnidaria (Coelentrata) (2 classes and 2 spp.), Arthropoda (2 classes and 33 spp.), Annelida (2 classes and 5 spp.) and Mollusca (2 classes and 19 spp.) in addition to larvae, pupae, nymphs and adult insects.

Density and biomass. Iskaros (1988) pointed out that the average annual number and biomass of bottom fauna recorded for Lake Nasser as a whole during 1986-1987 amounted to 2,659 ind./m^2 and 13.1 g fresh weight/m^2 (GFW), at the littoral zone, and 288 ind./m^2 and 1.9 g fresh weight/m^2 at the

profundal zone. These values were much lower than those recorded for Khor Kalabsha during 1989-1990, by the same author, where the standing crop of bottom fauna reached 10,292 ind./m^2 and 33.9 g fresh weight/m^2 at the littoral zone and 908 ind./$m^2$and 4.0 g fresh weight/m^2 at the profundal zone (Iskaros, 1993). Thus khors seem to be richer in benthic fauna than the main channel.

Fishar (1995) studied the distribution of bottom fauna in Lake Nasser main channel in 1993 as well as the eastern and western sides and pointed out that the standing crop of bottom fauna for Lake Nasser as a whole averaged 823 ind./m^2/year, weighing 4.776 g fresh weight/m^2/year. The bottom fauna showed a high population density (PD)[x**] in Amada section, where 1236 ind./m^2/year weighing 7.04 g fresh weight/m^2/year were recorded. This value decreased gradually towards the northern and southern sections. The lowest population density was recorded at the southernmost locality (Adindan section) with an average value of 331 ind./m^2/year weighing 1.672 g fresh weight/m^2/year (Fig. 100). In the main channel stations, the population density and biomass (BM) of total bottom fauna remained low, attaining average values of 556 ind./m^2/year, and 3.192 g fresh weight/m^2. The highest values (1027 and 887 ind./m^2/year) were recorded at the eastern and western stations respectively (Fig. 100 - Fishar 1995).

A reverse picture was observed on the biomass values. Thus, the biomass values of bottom fauna in the western side of the lake were higher than those recorded in the eastern one. This increase in the biomass was associated with the increase of Mollusca at stations of Dihmit, Mariya and El-Madiq, and heavy crustaceans in Amada and annelids at Dihmit stations (Fishar 1995). Table 75 shows the results of Absolute Importance Value (AIV)[*] and Relative Importance Value (RIV)[**] of the total bottom fauna in Lake Nasser. Amada section occupies the first rank on the AIV scale, where a value of 19.65 was recorded, followed by Mariya section. While, the lowest AIV was found at El Madiq section followed by Tushka section and at last in the upstream section.

Species diversity, density and biomass

In Lake Nasser, aquatic insects, molluscs and annelids are important organisms as food for fishes and their diversity, density and biomass are as follows:

1. Aquatic insects are the most important organisms among the benthic fauna community in Lake Nasser. They form 77.8%, with an average 2072 larvae/m^2 and constitute by weight 16.1% (average 8.0 g fresh weight/m^2) of the total

---

[*]Absolute Importance Value Index (A I V) = Log (PDxBMxAF) [Ghabbour and Shakir 1980]

AF = Absolute frequency = Number of occurrences of a taxon in the sampling unit

[x**] PD = Population density BM = Biomass (g fresh weight)

RF= Relative frequency = number of occurrences of taxon to the total occurrences of all taxa in the sampling unit

[**] Relative Importance Value Index (R I V) = % PD + % BM + % RF[Ghabbour and Shakir 1980]

benthos at littoral areas. At the profundal zone, these values decrease to 196 insect/m^2 and 0.4 g fresh weight/m^2 of the biomass. Their maximum distribution is recorded at the northern and middle sectors in winter and autumn (Iskaros 1988).

The aquatic insects recorded in Lake Nasser include 5 orders: Diptera (mainly chironomid larvae and pupae), Odonata (nymphs), Ephemeroptera, Trichoptera and Hemiptera (adult Corixidae). Wirth & Stone (1968) pointed out that chironomid larvae appear more abundant in shallow waters favoured by heavy growth of aquatic plants. In the littoral areas of Lake Nasser during 1986-1987, insect larvae formed numerically about 92.1% of the total insects (average 1909 larvae/m^2) and 40.0% of their biomass (average 3.2 g fresh weight/m^2). Entz (1978) pointed out that during the early years of impoundment, chironomids developed in enormous numbers in shallow freshwater areas of Lake Nasser, huge swarms of chironomids may occur within few years, probably due to the progressive inundation of the cultured river valley rich with soil. Iskaros (1988) mentioned that, at the profundal zone, the average counts of insects decreased to 196 larvae/m^2.

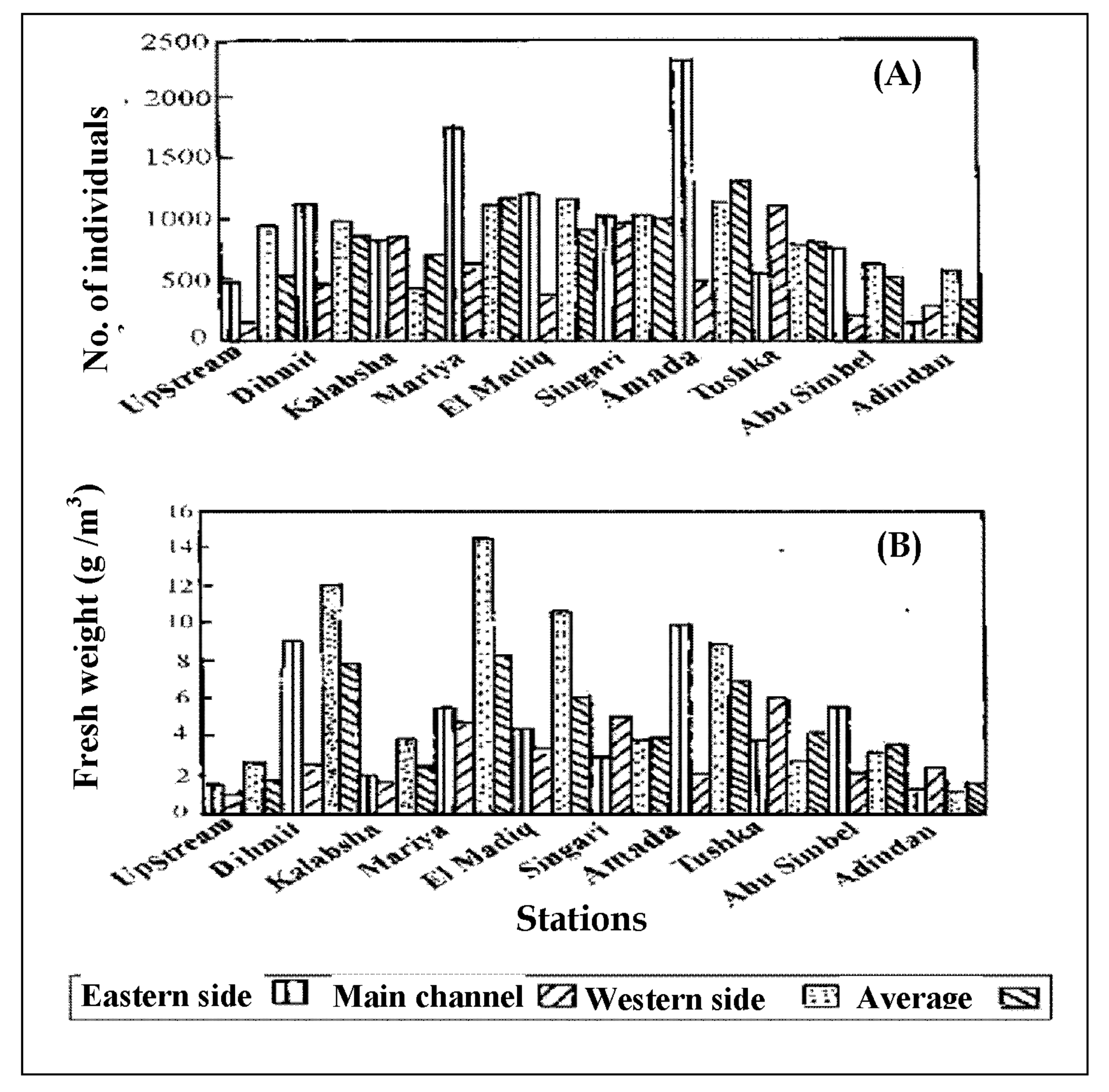


Fig. 100 **Distribution of A: population density, and B: biomass of total bottom fauna in different localities of Lake Nasser (Fishar 1995) [**For stations refer to Fig. 15**].**

Table 74 **Checklist of benthic invertebrates recorded in Lake Nasser by different authors (+ = Present, - = Not recorded).[Plates 14-16]**

Taxa and species	Elewa (1987b)	Iskaros (1988 & 1993)	Fishar (1995)
Phylum : Cnidaria			
Class : Hydrozoa			
Hydra vulgaris Pallas, 1766	-	-	+
Phylum : Bryozoa			
Class : Phyleclolaemata			
Fredericella sultana (Blumenbach, 1779)	-	-	+
Phylum : Arthropoda			
Class : Insecta			
Ablabesmyia sp.	-	+	+
Caenis sp.	-	-	+
Chironomus sp.	-	+	+
Circotopus sp.	-	+	+
Clinotanpus sp.	+	+	-
Coelotanpus sp.	-	+	+
Conchopelopia sp.	-	+	-
Cryptochironomus sp.	+	+	+
Dicrotendipes modestus	-	+	-
Einfeldina sp.	-	+	-
Enallagma sp.	-	-	+
Gomphus sp.	-	+	-
Ischnura sp.	-	-	+
Libellula sp.	-	+	-
Microchironomus sp.	-	+	-
Micronecta plicata	-	-	+
Microtendipes sp.	+	+	+
Neurocordula sp.	-	-	+
Nilodorum sp.	-	+	+
Pelopia sp.	-	+	-
Plathemis sp.	-	-	+
Polypedilum sp.	-	+	+
Perithemis sp.	-	+	+
Procladius sp.	+	+	+
Pseudoagrion niloticus	-	+	-
Tanpus sp.	-	+	-
Dytiscide sp.	-	-	+
Tanytarsus sp.	+	+	+
Hydrovatus sp.	-	-	+
Larvae of Trichoptera	+	+	+
Pupae of Chironomidae	-	-	-
Nymphs of Ephemeroptera	-	+	-
Adult of Corixidae	-	+	-
Class : Crustacea			
Cardina nilotica (P. Roux, 1833)	-	-	+
Chlamydotheca unispinosa Baird, 1862	-	-	+
Potamonautes niloticus (H. Milne Edwards)	-	-	-
Stenocypris malcolmsoni Baired, 1862	-	-	+

Phylum : Annelida			
Class : Oligochaeta			
Branchiura sowerbyi Beddard, 1892	+	+	+
Limnodrilus hoffmeisteri Claparéde, 1862	+	+	+
Limnodrilus udekemianus Claparéde, 1862	+	+	+
Pristina sp.	-	-	+
Class : Hirudinea			
Helobdella conifera (Moore, 1933)	-	+	+
Phylum: Mollusca			
Class : Gastropoda			
Bellamya unicolor (Olivier, 1804)	-	+	-
Biomphalaria alexandrina (Ehrenberg, 1831)	-	+	-
Bulinus truncatus (Audouin, 1827)	+	+	+
Bulinus forskalii (Ehrenberg, 1831)	-	+	-
Cleopatra bulimoides (Olivier, 1804)	-	+	+
Gabbiella senaariensis (Kuster, 1852)	-	+	-
Helisoma duryi (Wetherbg, 1879)	-	+	-
Lanistes carinatus (Olivier, 1804)	-	+	-
Lymnaea natalensis Krauss, 1848	-	+	-
Melanoides tuberculata (Müller, 1774)	+	+	+
Physa acuta Darparnaud, 1805	+	+	+
Pila ovata (Olivier, 1804)	-	+	-
Segmentorbis angustus (Jickeli, 1874)	-	+	-
Theodoxus niloticus (Reeve, 1856)	-	+	-
Valvata nilotica Jickeli, 1874	+	+	+
Gyraulus ehrenbergi (Beck, 1837)	-	-	+
Class : Bivalvia			
Corbicula consobrina (Cailliaud, 1827)[1]	+	-	+
Pisidium pirothi Jickeli, 1881	+	-	+
Eupera ferruginea (Krauss, 1848)[2]	-	-	+
Total = 63 species	**15**	**43**	**39**

1- Misidentified by the author (Fishar 1995) as *C. fluminalis*

2- Misidentified by the author (Fishar 1995) as *Sphaerium simili*

In Lake Nasser, chironomid larvae belong to 3 subfamilies, viz. Chironominae (8 species), Tanypodinae (6 species) and Orthocladiinae (one species). According to their relative abundance, they constituted 76.1, 23.8 and 0.1% respectively of the total number of chironomid larvae (Iskaros 1988). The dominance of Chironominae in reservoirs is probably related to their tolerance to reduced oxygen concentration and their ability to exploit newly flooded terrestrial vegetation (Rosenberg *et al.* 1984).

Furthermore, the distribution of Odonata nymphs in Lake Nasser was confined to the littoral areas (Iskaros 1988). Their average annual number amounted to 70 nymphs/m^2, constituting numerically about 3.4% of the total insects. Nevertheless, their biomass increased to 55% of their weight (average 4.4 g fresh weight/m^2). This is attributed to the large size of anisopteran nymphs. Iskaros (1988) pointed out that Ephemeroptera nymphs, Trichoptera larvae and Corixidae were scarcely recorded at the littoral areas.

2. Molluscs. In Lake Nasser, Mollusca represent the second important bottom dwellers inhabiting the littoral areas. They form about 11.9 and 9.2% by numbers and weight respectively (the average number 317 ind./m^2 and the average weight 1.2 g fresh weight/m^2) (Iskaros 1988). They appear in

maximum numbers at the northern region, particularly in spring and summer. On the other hand, their occurrence is very rare (average annual number 3 ind./m^2) at the profundal zone (Iskaros 1988).

It seems that water temperature controls the distribution of molluscs in Lake Nasser. Iskaros (1993) regarded that their numbers inhabiting the littoral areas of Khor Kalabsha increased gradually throughout winter and spring, reaching their peaks in May and/or June. This is mainly due to the increased fecundity of individuals along with the increase of water temperature. The latter author found that late winter and spring were the most productive periods for *Physa acuta* and *Bulinus truncatus*, while a sharp drop in their numbers took place when water temperature exceeded 27.5 °C. The gastropod *Valvata nilotica* appeared at the littoral areas of Khor Kalabsha during spring and summer, showing a persistence in June and August and disappearing mostly throughout autumn and winter. In the profundal areas, this gastropod occurred mainly in winter and spring and became rare in summer and autumn. This indicates a downward migration of this species during the cold season, but the development of the thermocline during the summer forced it to return for an upward migration in the well-oxygenated layer.

The Lake's old bed was inhabited by a very dense population of bivalves. During the stagnation period, with the formation of the Lake, these bivalves died and disappeared. Starting from 1973, mussels and oligochaetes resettled in the shallow inlet water of the khors due to the continuous favourable oxygen conditions (Entz 1976).

3. Annelids (Oligochaetes). Oligochaetes represent the third important component among the benthic community at the littoral zone of Lake Nasser. They form numerically about 10.2 % (average 270 ind./m^2)and 29.8% of their biomass (average 3.9 g fresh weight/m^2). On the other hand, oligochaetes rank second in importance at the profundal zone where they form numerically about 30.5% of the total fauna (average 88 ind./m^2) and 73.7% of its biomass (average 1.4 g fresh weight/m^2). Their maximum distribution appears at the northern sector of the Lake, particularly in summer of 1986 (Iskaros 1988). The prevalence of oligochaetes in the littoral zone of Khor Kalabsha during October 1989-September 1990 was confined to spring and summer, and disappeared in autumn and winter (Iskaros 1993). At the profundal zone of Khor Kalabsha, oligochaetes were more abundant throughout most of the year, indicating that the variation of water temperature is not a determining factor for seasonal distribution. The factor of prey-predator interactions may have a controlling effect on the distribution of oligochaetes. Iskaros (1988 and 1993) reported an inverse relation between

the abundance of chironomid larvae and oligochaetes, which are mainly consumed by the high density of such chironomid larvae. The predation of chironomids on oligochates was emphasized by Loden (1974), who found setae of oligochaete species in the gut contents of 13 species belonging to Chironominae and Tanypodinae.

Table 75 **Absolute importance value (AIV)* and relative importance value (RIV)** of bottom fauna in different localities of Lake Nasser during 1993 (Fishar 1995).**

Taxa and species	Upstream		Dihmit		Kalabsha		Mariya		El Madiq		Singari		Amada		Tushka		Abu Simbel		Adindan	
	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV
Phylum : CNIDARIA																				
Class : Hydrozoa																				
Hydra vulgaris	-	-	-	-	0.830	8.980	-0.030	2.210	-	-	-	-	0.670	2.660	0.480	5.170	-	-	-	-
Phylum: BRYOZOA																				
Fredericella sultana	0.080	5.080	-0.570	2.840	1.690	13.710	2.310	7.500	-0.300	2.560	-	-	-0.330	2.330	-1.700	3.700	-	-	-	-
Phylum : ARTHROPODA																				
Class : Insecta	3.170	34.790	3.970	41.830	3.990	66.920	4.620	54.890	4.880	81.620	4.380	54.920	5.040	70.280	3.110	22.670	4.370	84.810	3.060	44.510
Ablabesmyia sp.	1.770	5.010	3.060	83.260	0.500	2.890	1.630	11.850	2.240	16.140	2.610	48.190	1.180	5.970	-0.870	6.620	1.680	21.290	0.750	23.860
Caenis sp.	-	-	-0.400	8.620	-	-	1.720	12.720	1.760	11.030	-	-	-	-	-	-	-	-	-	-
Chironomus sp	-	-	-	-	-	-	0.160	2.200	-	-	-	-	-	-	-	-	-	-	-	-
Circotopus sp.	-	-	-	-	-	-	-	-	-	-	0.320	5.170	-0.520	2.480	-	-	-	-	-	-
Coelotonypus sp.	1.340	30.820	-	-	-	-	1.930	19.370	-1.000	2.470	0.430	6.160	-0.300	2.630	-	-	-	-	0.390	11.010
Cryptochironomus sp.	-	-	-1.480	3.010	-	-	-1.000	2.510	1.840	12.120	-1.180	3.050	-0.400	2.560	-	-	-	-	0.780	28.510
Enallagma sp.	-	-	-	-	-0.004	5.080	0.430	5.030	-	-	-	-	2.770	42.260	-	-	-	-	-	-
Ischnura sp.	0.750	22.290	-	-	0.110	6.400	0.200	4.390	-0.700	2.700	-	-	-	-	-	-	-	-	-	-
Micronecta plicata	-	-	1.040	13.600	-	-	-	-	-	-	-	-	0.570	9.730	0.920	26.140	-	-	-	-
Microtendipes sp.	-	-	-	-	3.020	71.150	1.450	10.310	2.680	23.670	2.210	25.330	1.100	5.650	2.460	101.89	3.120	65.370	0.780	23.400
Neurocordula sp.	-	-	0.170	8.620	-	-	-	-	-	-	-	-	0.760	8.590	-	-	-	-	-	-
Nilodorum sp.	-0.870	5.690	1.670	22.890	2.920	18.850	3.730	93.300	2.230	17.840	2.180	24.400	3.420	55.870	1.570	51.660	0.170	5.120	0.380	19.230
Plathemis sp.	-	-	-	-	-	-	-	-	-	-	1.010	11.750	0.480	8.760	-	-	-	-	-	-
Polypedilum sp.	-	-	2.120	35.180	-	-	2.300	21.930	3.210	61.630	2.970	46.530	2.080	12.290	-	-	-	-	0.760	22.420
Prithemis sp.	-	-	-	-	-0.370	4.660	-	-	2.340	56.110	0.600	8.200	-	-	-	-	0.790	14.090	-	-
Procladius sp.	1.220	26.330	2.480	50.440	3.330	101.11	3.200	47.470	2.300	17.120	2.080	22.110	2.680	19.110	1.470	37.930	2.620	36.670	0.000	12.440
Tanytarsus sp.	1.940	77.790	1.160	16.390	-	-	-0.770	3.180	1.090	7.430	2.390	29.490	2.080	11.970	-	-	3.340	81.570	2.250	92.430

Cont. *Table 75*

Larvae of Trichoptera	-	-	-	-	-	-	-0.173	3.160	1.220	7.500	-1.780	3.240	-	-	-	-	-	-	0.220	12.740
Pupae of chironomidae	0.270	15.130	-0.050	5.840	-0.880	3.860	1.110	8.680	1.390	9.110	1.470	13.360	1.900	11.140	-	-	0.370	6.830	-	-
Class : Crustacea	2.570	26.100	3.830	31.450	2.250	14.640	2.670	11.580	2.320	11.030	3.090	18.460	4.780	49.870	2.110	14.940	2.270	14.870	1.880	18.370
Cardina nilotica	-	-	2.830	90.150	-	-	0.440	39.700	-	-	-	-	4.170	122.880	-	-	0.490	64.490	-	-
Chlamydotheca unispiosa	1.800	88.800	2.990	82.750	1.930	152.530	1.690	62.570	1.487	80.550	2.590	118.340	3.110	58.500	198.000	182.040	1.760	125.020	1.520	115.680
Stenocypris malcolmsoni	2.100	121.800	2.050	39.390	0.540	61.630	1.950	83.170	1.900	127.970	2.210	93.020	2.710	33.710	-0.080	31.750	0.120	25.640	0.860	46.380
Phylum : ANNELIDA	4.190	85.350	4.620	66.850	4.490	91.920	4.780	55.460	4.830	75.460	5.200	127.370	5.70	67.410	5.270	154.230	4.240	72.400	4.180	120.350
Class : Oligochaeta																				
Branchiura sowerbyi	1.110	13.520	2.650	31.780	-	-	2.690	28.560	2.740	26.630	2.010	12.290	2.900	24.090	3.060	26.780	2.550	42.320	-	-
Limnodrilus hoffmeisteri	3.070	63.140	3.350	65.060	2.810	39.980	2.160	16.130	4.520	147.910	4.520	98.740	3.940	60.520	4.480	93.850	2.900	59.090	2.170	39.480
Limnodrilus udedkemianus	3.620	112.325	3.640	71.010	4.080	133.740	3.790	72.700	2.670	24.740	4.460	91.810	4.240	83.530	4.610	106.430	3.660	115.450	3.950	164.250
***Pristina* sp.**	1.810	31.520	3.040	49.960	2.620	42.140	4.130	101.620	1.910	18.250	2.740	24.430	2.770	28.270	1.420	14.300	0.640	5.830	1.250	16.280
Class Hirudinea																				
Helobdella conifera	1.420	15.400	1.320	10.080	1.610	14.680	-0.300	2.900	0.930	7.930	-	-	-	-	-	-	-	-	-	-
Phylum : MOLLUSCA	3.880	74.300	4.590	84.850	3.410	39.950	5.200	95.430	4.370	54.980	3.570	26.510	4.420	33.880	3.740	40.680	3.820	58.200	3.240	52.770
Class : Gastropoda																				
Bulinus truncatus	1.030	12.670	3.380	60.230	-	-	4.020	49.890	2.770	61.410	-	-	1.440	11.950	-	-	-0.400	5.910	-	-
Cleopatra bulimoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.390	36.480	-	-
Melanooides tuberculata	2.220	55.680	-	-	1.570	30.290	3.120	26.560	3.540	99.110	2.680	102.890	2.980	61.070	2.130	41.420	2.730	83.950	1.660	43.850
Physa acuta	0.880	4.380	2.230	19.790	0.240	12.220	3.750	-	0.120	6.740	-	-	1.100	14.240	-1.000	7.300	-	-	-	-
Valvata nilotica	3.490	139.040	4.180	130.800	3.100	145.710	4.120	71.140	2.400	35.480	0.300	13.950	3.590	82.740	1.830	34.780	2.130	34.790	2.710	123.880
Gyraulus ehrenbergi	-	-	0.780	5.470	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Class : Bivalvia																				
Pisidium pirothi	1.000	5.070	-	-	0.080	10.170	-	-	1.260	16.410	2.650	99.090	2.890	48.680	3.390	140.650	2.420	57.280	1.830	56.260
Eupera ferruginea	0.060	6.230	-	-	0.085	20.670	-	-	-	-	-	-	-	-	-	-	0.480	5.830	-	-
Total	13.89	225.62	14.66	227.82	16.66	236.12	19.04	227.07	16.10	241.89	16.24	227.26	19.65	226.43	13.01	241.39	14.70	230.28	12.36	236.00

[For stations refer to Fig. 12]. * and ** For abbreviations refer to p. 208.

Entz (1976) was the only author who recorded the oligochaete *Tublifex* sp. in Lake Nasser which was estimated to be 60,000 ton. However, it seems that Entz's identification was erroneous as *Tubifex* sp. was mistaken for the oligochaete annelid *Branchiura sowerbyi* (personal communication with Prof. S. Gabbour)which was abundant in the Lake and was recorded by other authors (Table 74).*Tubifex* is known to be a boreal species and does not exist in Africa.

Oligochaetes were the only benthic forms inhabiting the profundal zone in Lake Nasser in summer, indicating their tolerance to low oxygen level. This observation confirms the findings of Eggleton (1931) in certain Michigan lakes who reported the disappearance of most benthos except *Tubifix* sp. with the development of summer stratification. This supports the view that *Tubifex* sp. previously recorded by Entz (1976) never existed in Lake Nasser, otherwise it would remain even at low oxygen concentrations.

Seasonal distribution. Fishar (1995) studied the seasonal variations of population density and biomass of the total bottom fauna in different localities of Lake Nasser (Fig. 101) and his results may be summarized as follows:

1. Winter. Numerically winter was the least productive season of the Lake's benthos producing an average of 610 ind./m^2. Pronounced variations in the population density between the sides were observed. The western side represented the most productive site producing an average of 876 ind./m^2. Also, the highest biomass value (5.014 g fresh weight/m^2) was recorded in the western side, while the biomass values were very low in the eastern side and the main channel, with average values together representing about 79 % of the biomass recorded in the western side.

2. Spring. The density of benthic organisms gained an increase, of 33.55 % of the value of the preceding season. The eastern side was the richest one (1038 ind./m^2). The population density showed a sharp increase in the main channel, and the standing crop was 3.9 times that during winter. Population density slightly increased in the western side with an average of 991 ind./m^2 Fig. 101). The average biomass of the main channel and the two sides proved to be richer than during winter. The highest average biomass (7.868 g fresh weight/m^2) was recorded in the western side (Fig. 101).

3. Summer. The average population density decreased to 804 ind./m^2 for the entire Lake. The highest value was recorded in the eastern side (960 ind./m^2). The standing crop in the main channel (774 ind./m^2) nearly equals that of the preceding season. At the western side the population density was 678 ind./m^2 being nearly 68.64% that of spring. Comparing the biomasses recorded in summer in the eastern side and the main channel with their corresponding values recorded in spring, reveals a sharp contrast.

Meanwhile, the biomass in the western side remained the same in spring and summer (Fig. 101).

4. Autumn. Numerically this season is the most productive one for the entire Lake, producing an average of 1013 ind./m^2. Pronounced variations were observed in the population density of both sides. The highest density (1460 ind./m^2) occurred in the eastern side, while the lowest average value (536 ind./m^2) was recorded in the main channel. Biomass values of benthic organisms showed a remarkable decrease than those observed in summer. Meanwhile, the biomass recorded in the western side was still higher than the values in the eastern side or in the main channel.

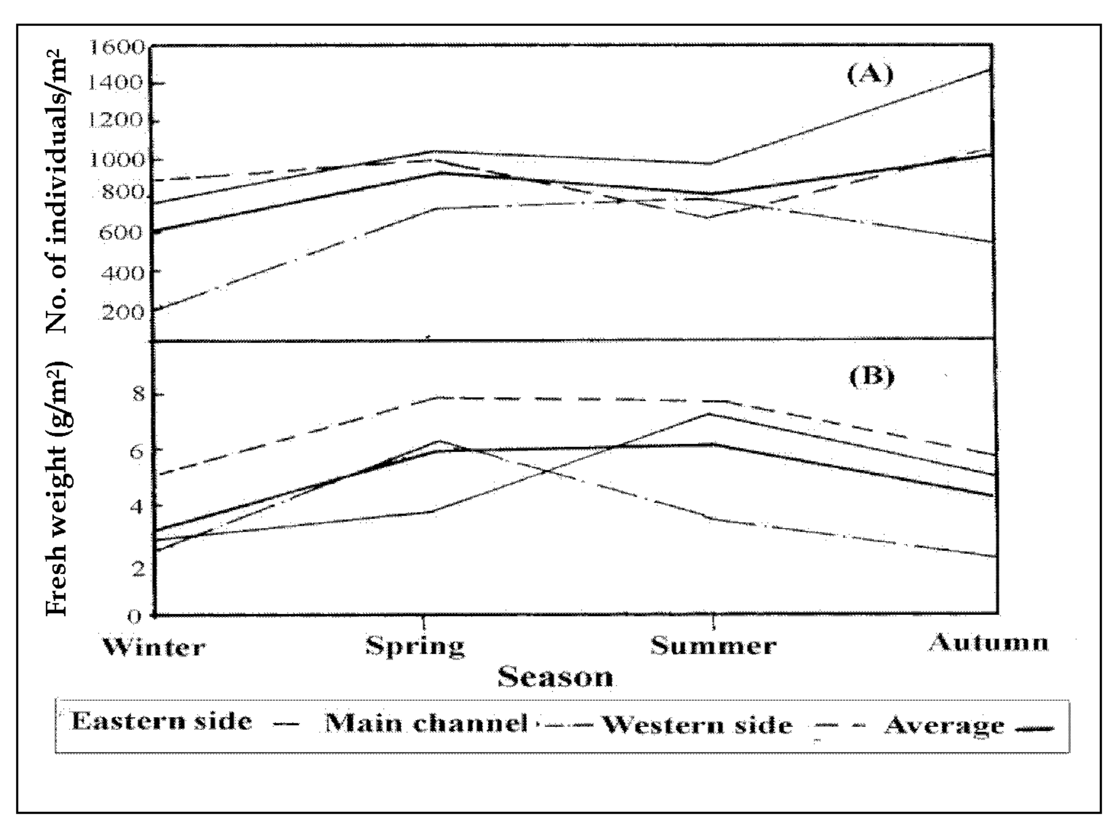


Fig. 101 **Seasonal variations of A: population density, and B: biomass of total bottom fauna in different localities of Lake Nasser during 1993 (Fishar 1995)** [For localities refer to Fig. 15].

The seasonal variations of absolute importance value (AIV) and relative importance value (RIV) of bottom fauna of Lake Nasser in 1993 show slight variations between different seasons (Table 76). Furthermore, the results show a slight increase in AIV value during spring for the total benthic groups. RIV also showed its highest value (223.29) in spring (Table 76).

Community composition. In Lake Nasser benthic organisms are rich and diversified. They are represented by 5 major groups, namely, Annelida (oligochaetes), Arthropoda (Insecta and Crustacea), Mollusca, Cnidaria

(Hydrozoa) and Bryozoa. Fishar (1995) mentioned that annelids and insects were the most common groups contributing 38.68 and 31.86% to the total benthic organisms (Fig. 102). Annelids are much heavier than the other components. They contributed 40.29% of the total biomass, followed by molluscs, which formed 36.16% of the total biomass. The percentages of biomass values were different from one side to other. Molluscs occupied the first position in both the eastern side stations (43.34%) and the western ones (47.74%), while annelids occupied the first position (90.40%) of the total benthic biomass in the main channel stations (Fig. 102). On the other hand, Bryozoa and Hydrozoa were less in population density and biomass, where 1.33 and 0.84% represented the population density of Bryozoa and Hydrozoa respectively, and 0.31 and 0.04% represented the respective percentages of biomasses. The distribution and seasonal variations of various benthic groups in the surveyed localities of Lake Nasser are shown in the Figs. 102-115.

In a complex natural environment, such as Lake Nasser, where several factors operate simultaneously, it is not easy to generalize and designate any one factor as being more important than the other. The biological processes taking place in the bottom of the Lake being the end result of the interactions of organisms present with the surrounding environment. Several abiotic and biotic factors are regarded as important in structuring stream macroinvertebrate communities, e.g. flow (Edington 1968), substratum (Reice 1980), allochthonous matter (Cummins & Klug 1979), temperature (Vannote & Sweeney 1980), chemistry (Sutcliffe & Hildrew 1989), predation (Allan 1983), and competition (Hart 1983).

The composition of benthic fauna has long been considered a good indicator of water quality because, unlike planktonic organisms, they form relatively stable communities in the sediments, which integrate change over long time intervals and reflect characteristics of both sediment and the water column (Aboul-Ezz 1984). The benthic fauna in Lake Nasser is rich and diversified. The general list includes, as mentioned before, 9 groups. It should be mentioned that the presence of certain species such as *Hydra vulgaris* is a bioindicator that Lake Nasser is unpolluted.

Successional Changes of Zoobenthos

Maclachlan (1974) pointed out that in a newly created lake the successional changes occur over a period of the order of ten to twenty years. Fishar (1995) identified three periods in the formation of the zoobenthos in Lake Nasser.

1. The first stage covered the early years of impoundment(1965-1969) where a mass of Chironomidae and Oligochaeta occurred in the littoral areas (Entz 1976) and the freshwater crab *Potamonautes niloticus* (Latif 1984a) were recorded.

Table 76 **Seasonal variations of absolute importance value (A I V) and relative importance value (R I V) of bottom fauna of Lake Nasser during 1993 (Fishar 1995).**

Taxa and Species	Winter		Spring		Summer		Autumn	
	AIV	RIV	AIV	RIV	AIV	RIV	AIV	RIV
Phylum : CNIDARIA								
Class : Hydrozoa								
Hydra vulgaris	0.030	4.410	0.330	2.660	-	-	0.080	3.610
Phylum : BRYOZOA								
Class : Phyleclolaemata								
Fredericella sultana	1.120	8.320	0.520	2.450	1.380	5.020	0.120	3.990
Phylum : ARTHROPODA								
Class : Insecta	3.910	51.010	4.570	59.080	3.900	36.010	4.510	62.86
Ablabesmyia **sp.**	2.060	10.000	2.330	8.510	2.100	9.340	1.50	7.71
Caenis **sp.**	0.880	3.600	1.000	3.370	-1.180	1.940	0.300	1.93
Chironomus **sp.**	-1.097	1.940	-	-	-	-	-	-
Circotopus **sp.**	-	-	-0.400	2.050	-	-	-1.480	1.59
Coelotanypus **sp.**	1.020	5.190	-	-	0.860	4.370	0.150	2.1
Cryptochironomus **sp.**	1.870	4.150	0.130	2.340	-0.700	3.500	0.560	3.76
Enallagma **sp.**	0.301	2.290	1.550	4.990	-0.880	1.850	0.990	4.13
Ischnura **sp.**	-1.220	3.380	0.390	4.120	-1.180	1.820	-1.480	1.59
Micromecta plicata	-	-	0.870	4.350	0.200	3.830	-1.430	1.590
Microtendipes **sp.**	1.810	9.500	2.540	10.890	2.160	9.340	2.750	11.87
*Neurocordul***a sp.**	0.156	3.280	-	-	-	-	-	-
Nilodorum **sp.**	2.340	12.840	2.050	7.200	1.260	5.300	3.590	27.38
Plathemis **sp.**	0.176	3.350	0.120	2.210	-	-	-	-
Polypedilum **sp.**	1.880	8.900	2.880	14.780	1.080	6.150	2.450	10.19
Perithemis **sp.**	-	-	1.780	8.680	-0.250	2.060	0.360	3.55
Procladius **sp.**	1.400	6.450	2.990	14.200	2.970	17.690	2.500	10.12
Tanytarsus **sp.**	1.760	9.490	2.090	7.440	1.490	5.430	2.180	7.74
Larvae of Trichoptera	0.080	4.030	-0.480	1.960	-	-	0.030	2.050
Pupae of Chironomidae	0.505	4.530	-0.880	1.910	1.320	6.690	1.340	4.97
Class : Crustacea	3.590	38.180	2.820	13.900	2.320	12.650	3.910	32.580
Cardina nilotica	3.070	30.020	-	-	-	-	2.720	13.560
Chlamydotheca unispinosa	1.960	10.150	2.460	10.810	1.600	7.780	2.940	14.900
Stenocypris malcolmsoni	-0.160	6.060	1.860	8.160	1.640	8.200	2.760	12.490
Phylum : ANNELIDA	4.570	99.350	5.020	91.810	4.960	90.320	4.560	63.89
Class Oligochaeta								
Branchiura sowerbyi	2.790	17.670	3.080	14.500	2.020	6.850	1.000	4.16
Limnodrilus hoffmeisteri	3.190	24.040	4.480	52.180	3.520	21.780	3.590	25
Limnodrilus udekemianus	4.085	58.680	3.880	28.380	4.360	47.940	3.920	33.45
Pristina **sp.**	2.120	12.800	1.850	9.790	3.790	27.070	2.330	11.74
Class Hirudinea								
Helobdella conifera	-0.330	2.270	1.320	35.260	-	-	1.030	4.21
Phylum : MOLLUSCA	2.990	22.870	4.450	53.400	4.790	79.300	4.150	55.110
Class : Gastropoda								
Bulinus truncatus	0.030	3.850	3.230	24.450	2.570	10.800	2.680	18.660
Cleopatra bulimoides	-	-	-	-	-	-	0.570	4.240
Melanoides tuberculata	1.190	7.500	2.600	14.750	3.090	17.510	2.580	13.590
Physa acuta	-0.480	2.120	0.970	4.990	2.890	14.790	1.640	5.490
Valvata nilotica	2.340	12.050	3.030	13.880	4.090	37.050	3.200	18.050
Gyraulus ehrenbergi	-	-	-	-	-0.570	1.980	-	-
Class : Bivalvia								
Pisidium pirothi	0.750	3.700	2.330	8.620	2.790	11.990	2.230	7.960
Eupera ferruginea	0.160	3.280	-	-	-1.180	1.820	-1.000	1.740
Total	17.21	224.14	17.71	223.29	17.35	223.30	17.33	222.04

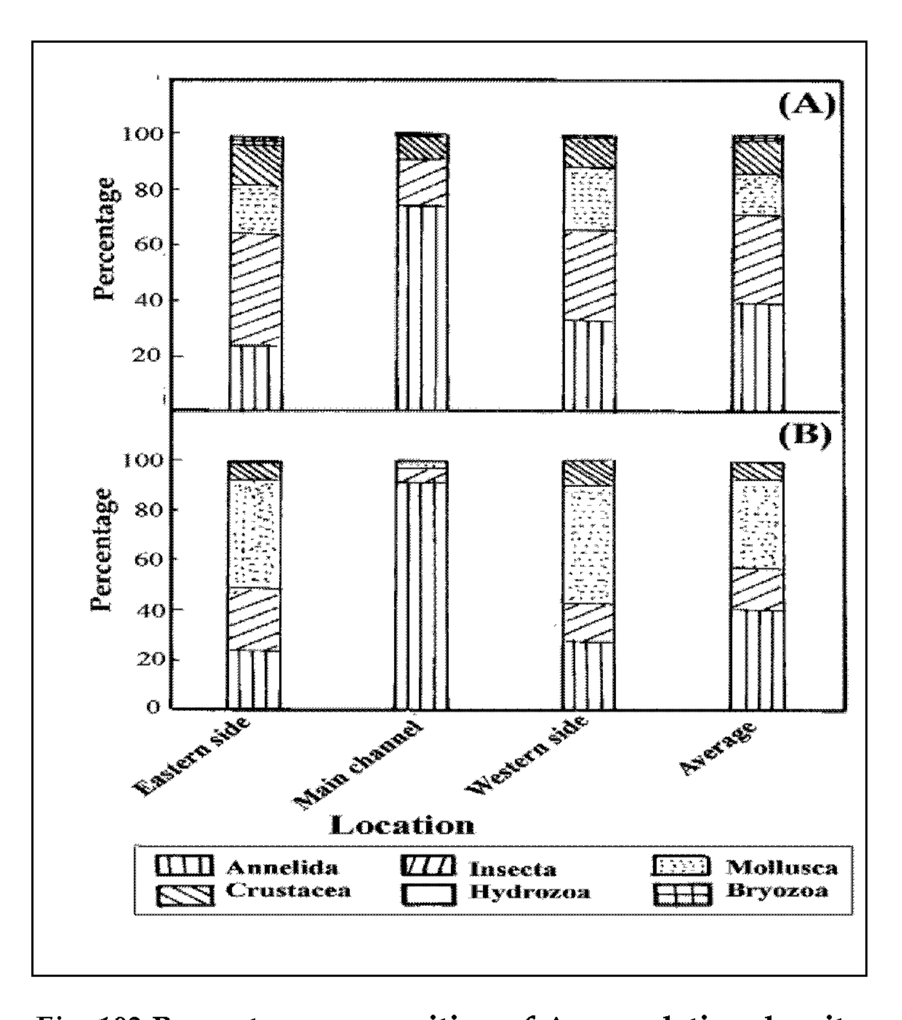


Fig. 102 **Percentage composition of A: population density, and B: biomass of benthic groups in Lake Nasser (Fishar 1995) [**For localities refer to Fig. 15**].**

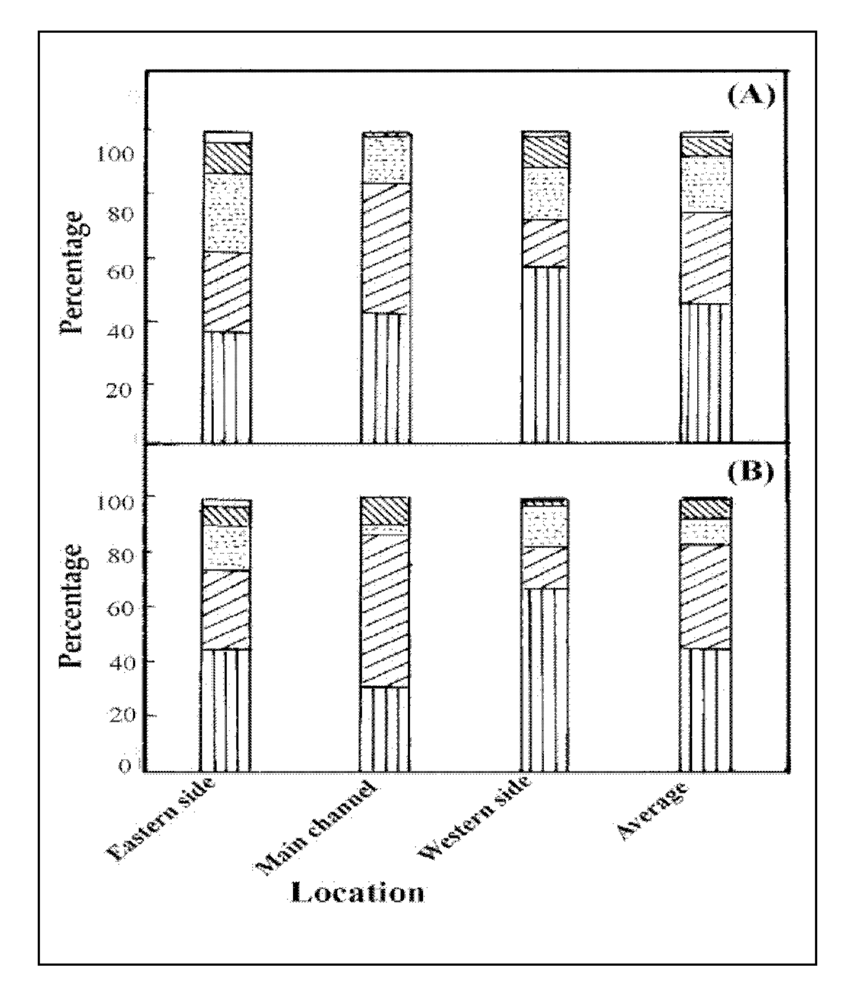


Fig. 103 **Percentage composition of A: population density, and B: biomass of Annelida in Lake Nasser (Fishar 1995) [**For localities refer to Fig. 15**].**

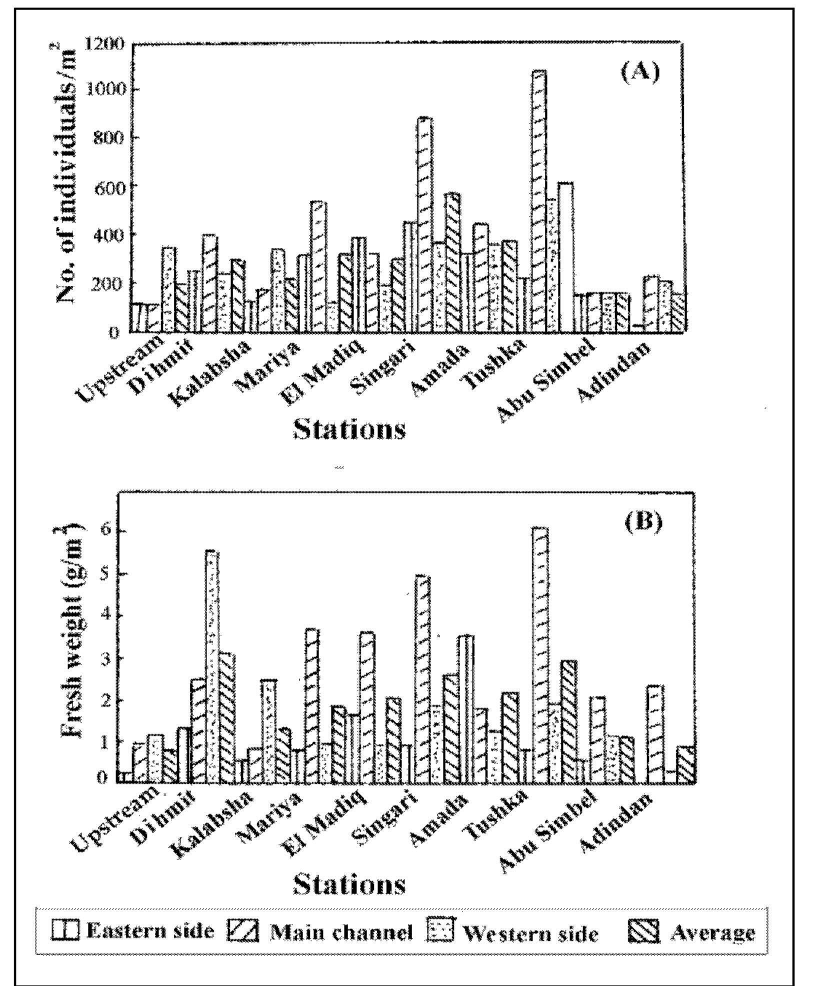


Fig. 104 **Distribution of A: population density, and B: biomass of Annelida at different localities of Lake Nasser. (Fishar 1995) [**For stations refer to Fig. 15**].**

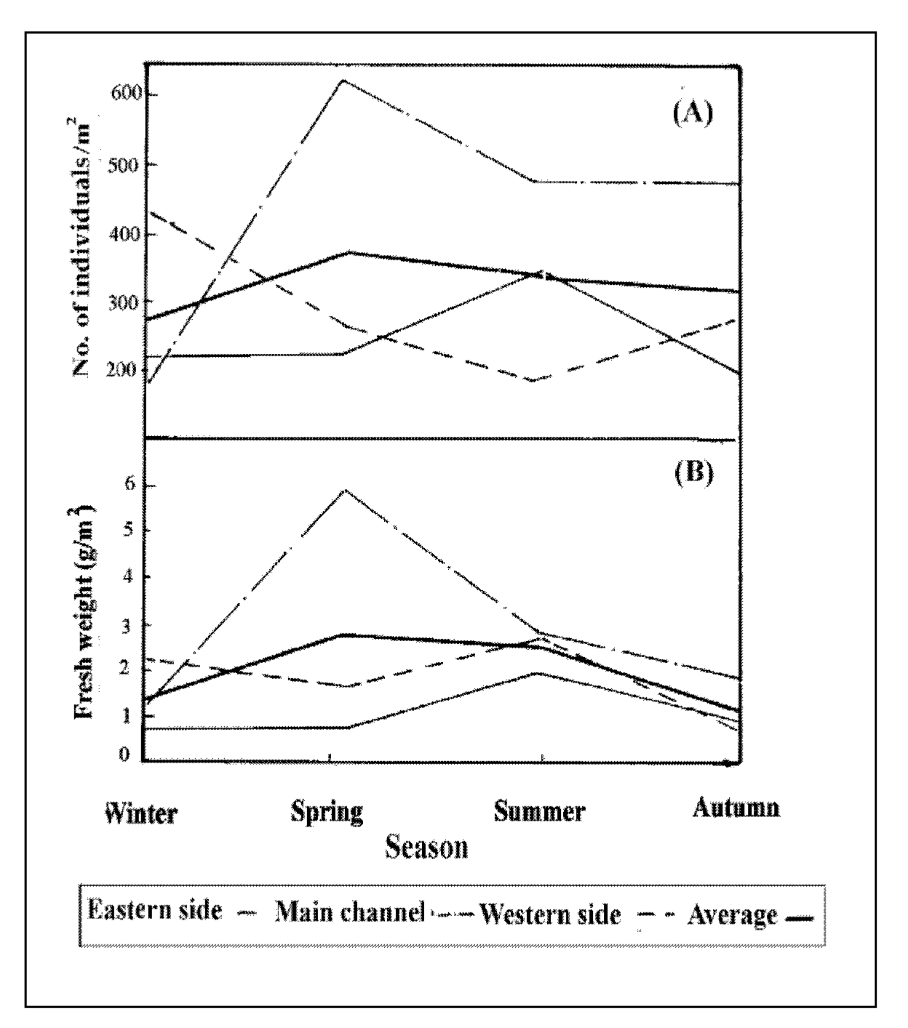


Fig. 105 **Seasonal variations of A: population density, and B: biomass of Annelida at different localities of Lake Nasser during 1993 (Fishar 1995) [**For stations refer to Fig. 15**].**

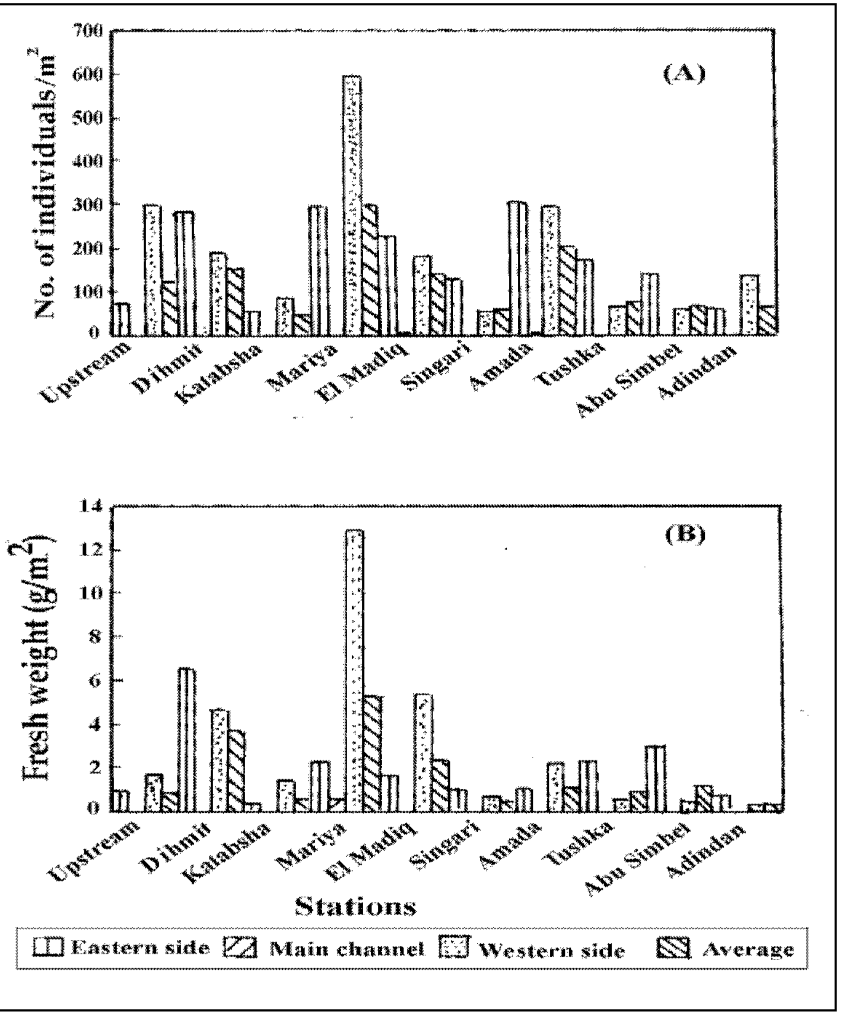


Fig. 106 **Distribution of A: population density, and B: biomass of Mollusca in different localities in Lake Nasser (Fishar 1995)** [For localities refer to Fig. 15]

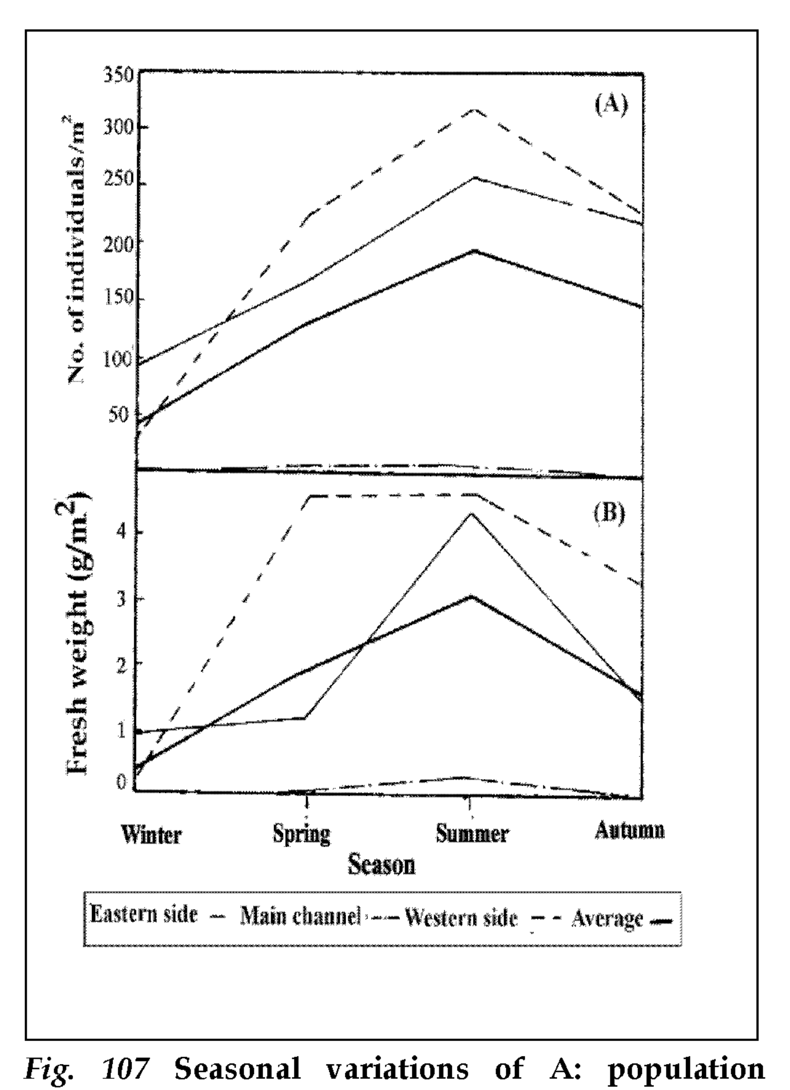


Fig. 107 **Seasonal variations of A: population density, and B: biomass of Mollusca in different localities of Lake Nasser during 1993 (Fishar 1995)** [For localities refer to Fig. 15].

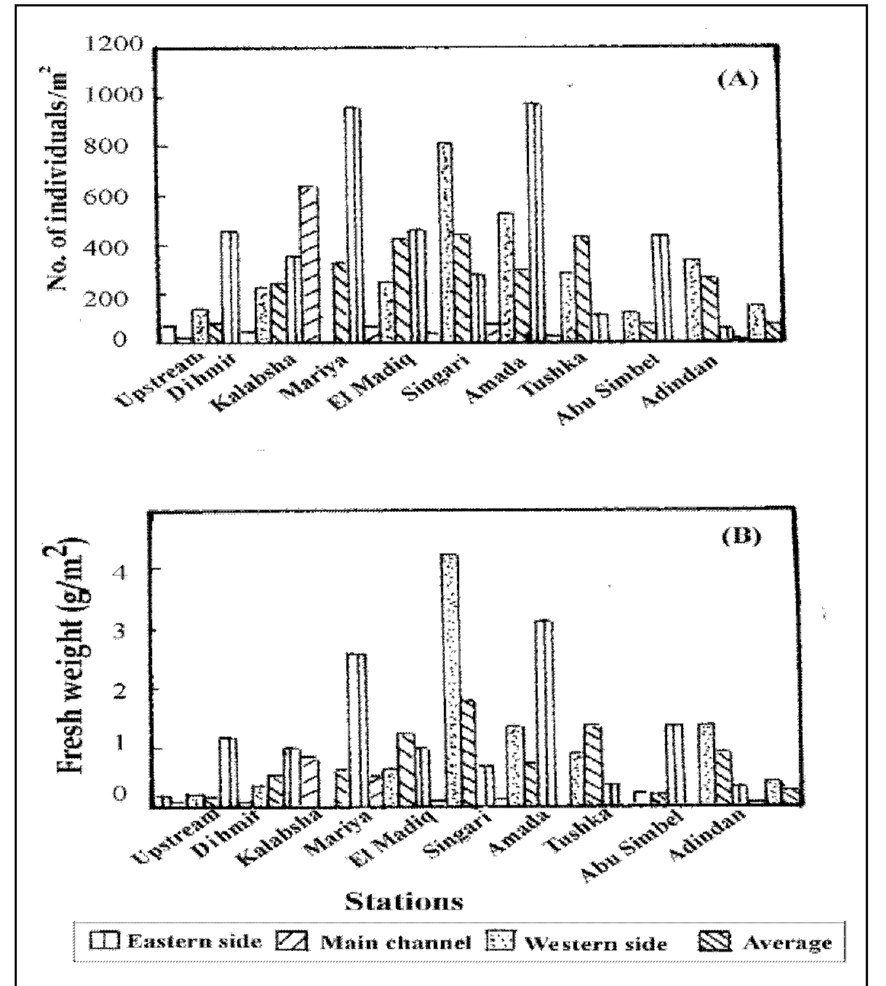


Fig. 108 **Distribution of A: population density, and B: biomass of Insecta recorded in different localities of Lake Nasser (Fishar 1995) [**For localities refer to Fig. 15**].**

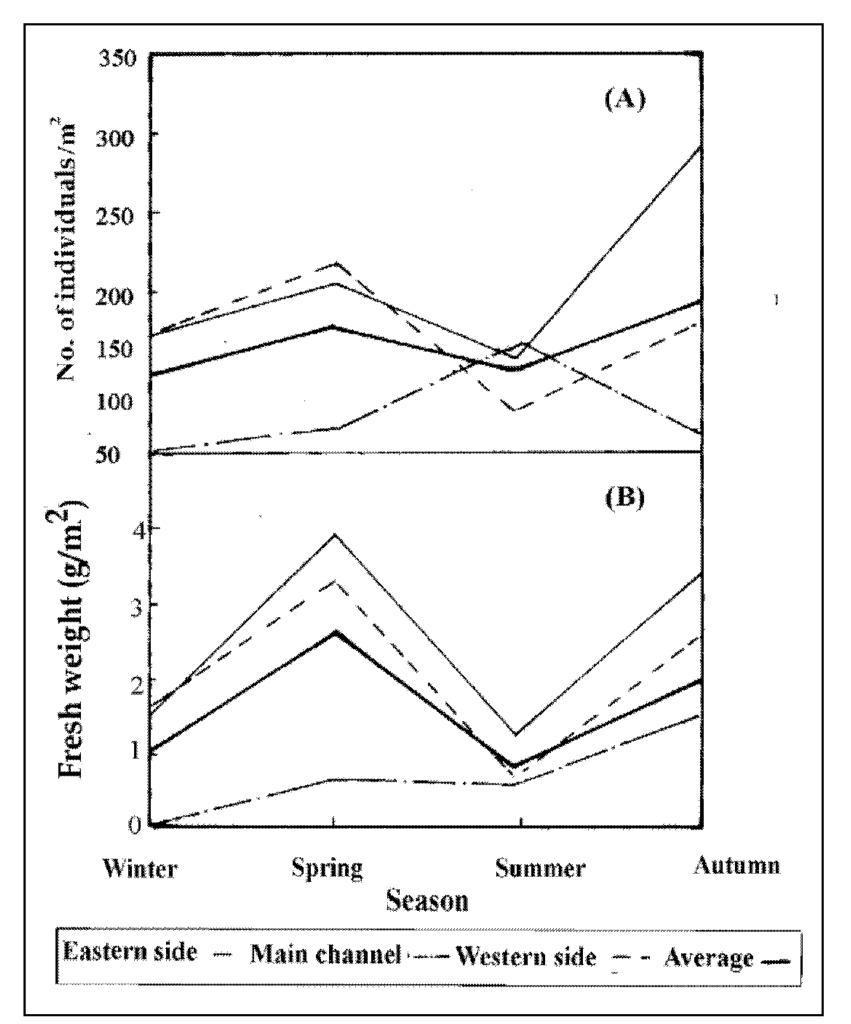


Fig. 109 **Seasonal variations of A: population density, and B: biomass of total Insecta in different localities of Lake Nasser (Fishar, 1995) [**For localities refer to Fig. 15**].**

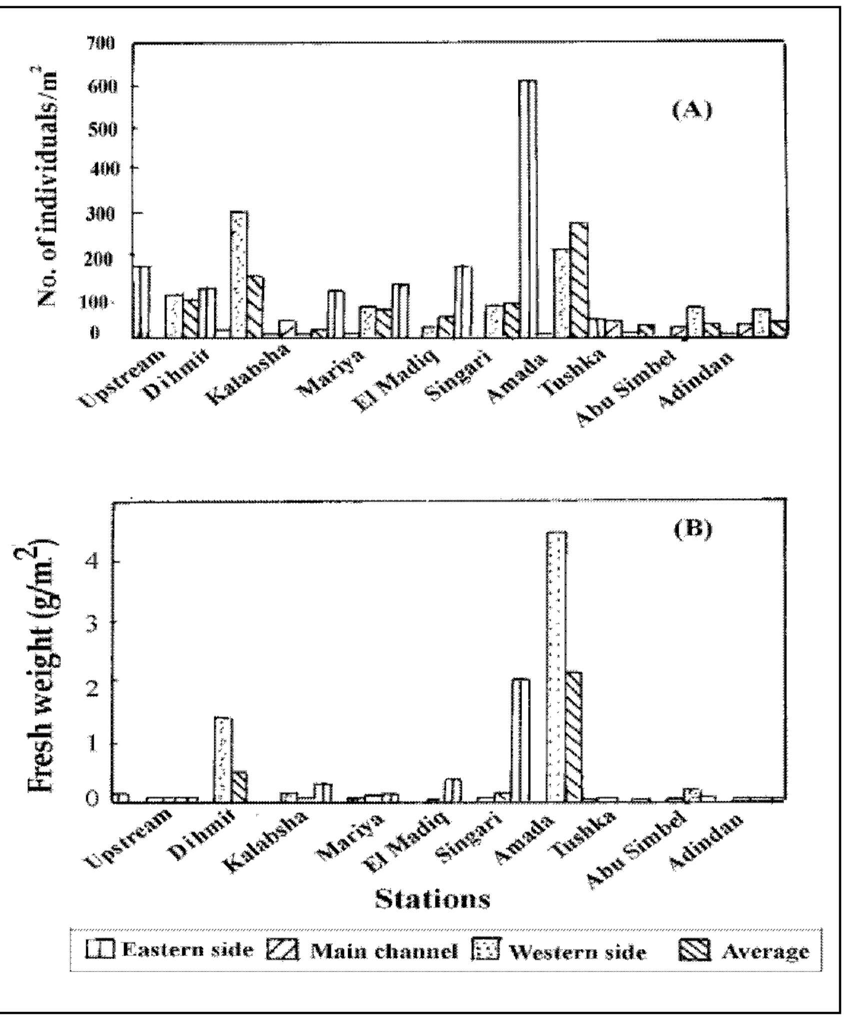


Fig. 110 **Distribution of A: population density, and B: biomass of Crustacea in different localities in Lake Nasser (Fishar 1995) [**For localities refer to Fig. 15**].**

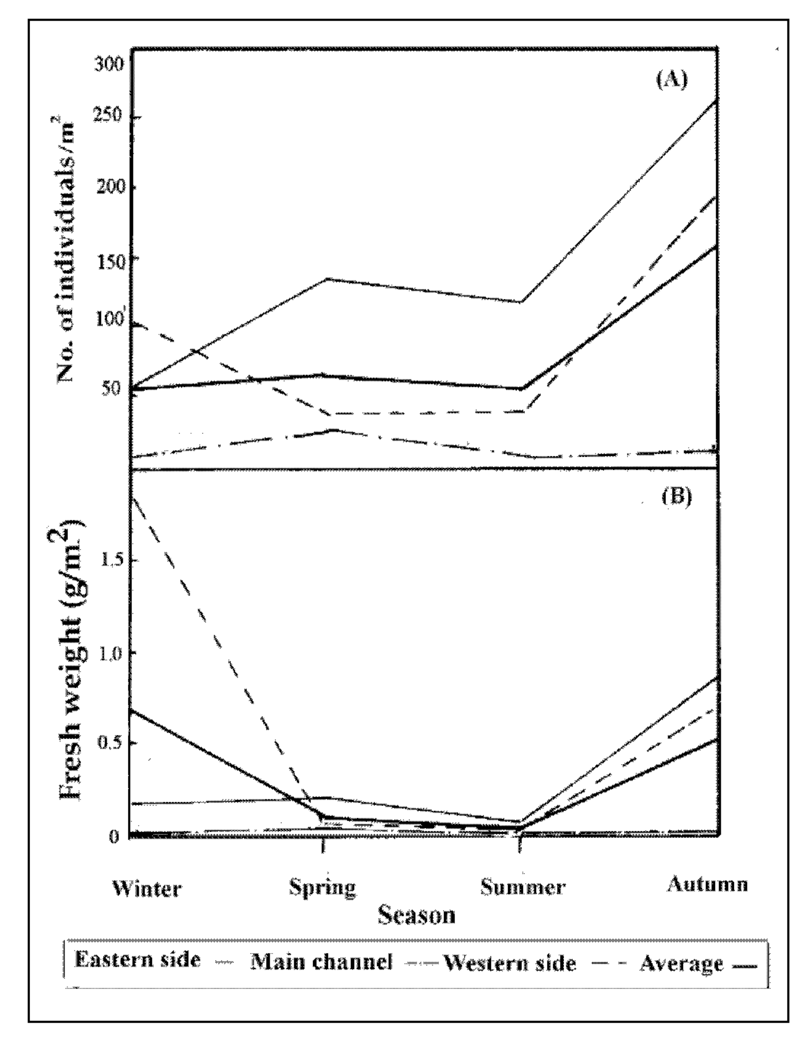


Fig. 111 **Seasonal variations of A: population density, and B: biomass of Crustacea in different localities of Lake Nasser during 1993 (Fishar 1995) [**For localities refer to Fig. 15**].**

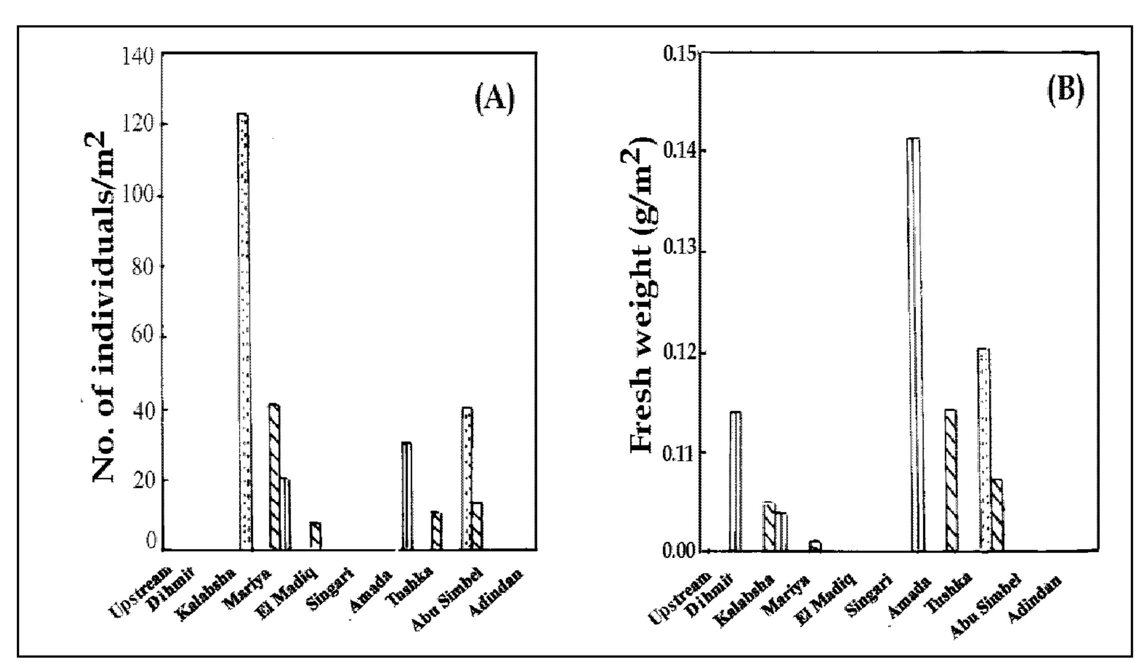


Fig. 112 **Distribution of A: population density, and B: biomass of *Hydra vulgaris* at different sites of Lake Nasser (Fishar 1995) [**For stations refer to Fig. 15**].**

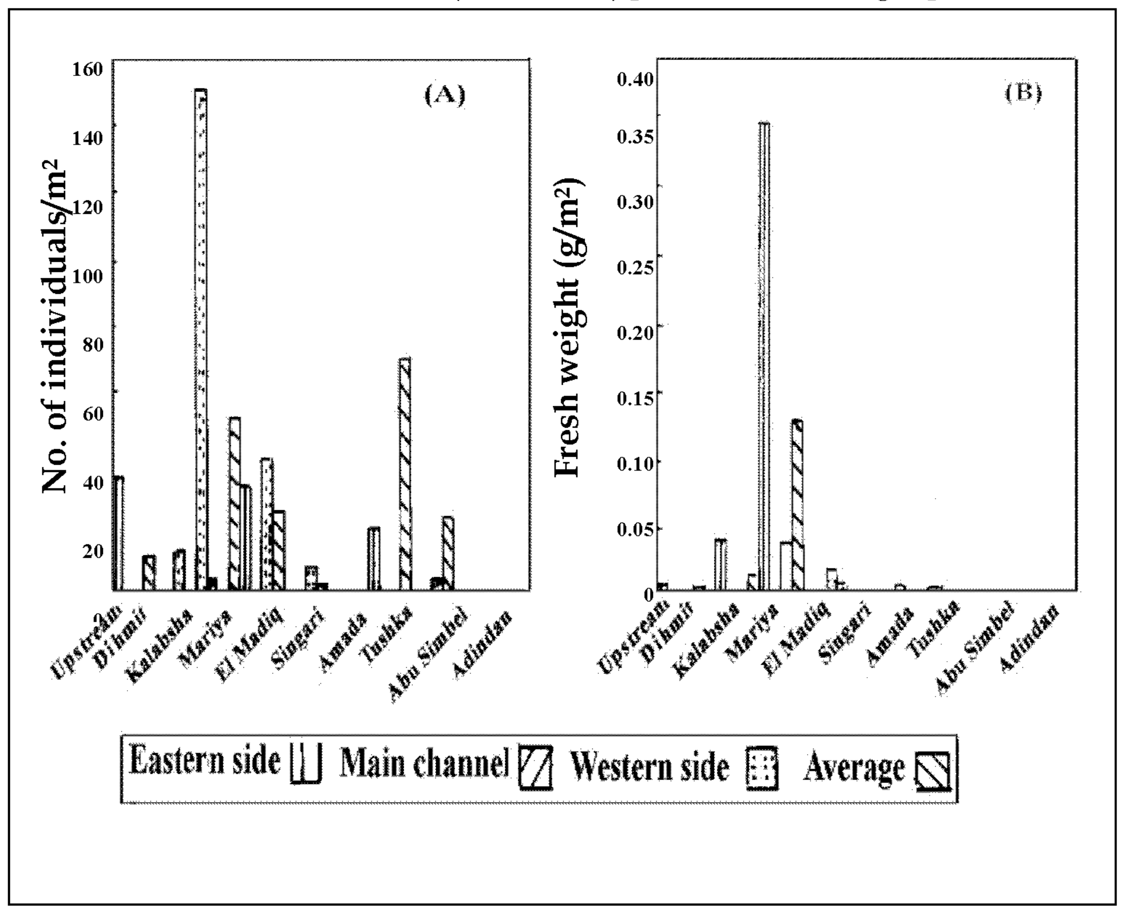


Fig. 113 **Distribution of A: population density, and B: biomass of *Fredericella sultana* at different localities of Lake Nasser (Fishar 1995) [**For stations refer to Fig. 15**].**

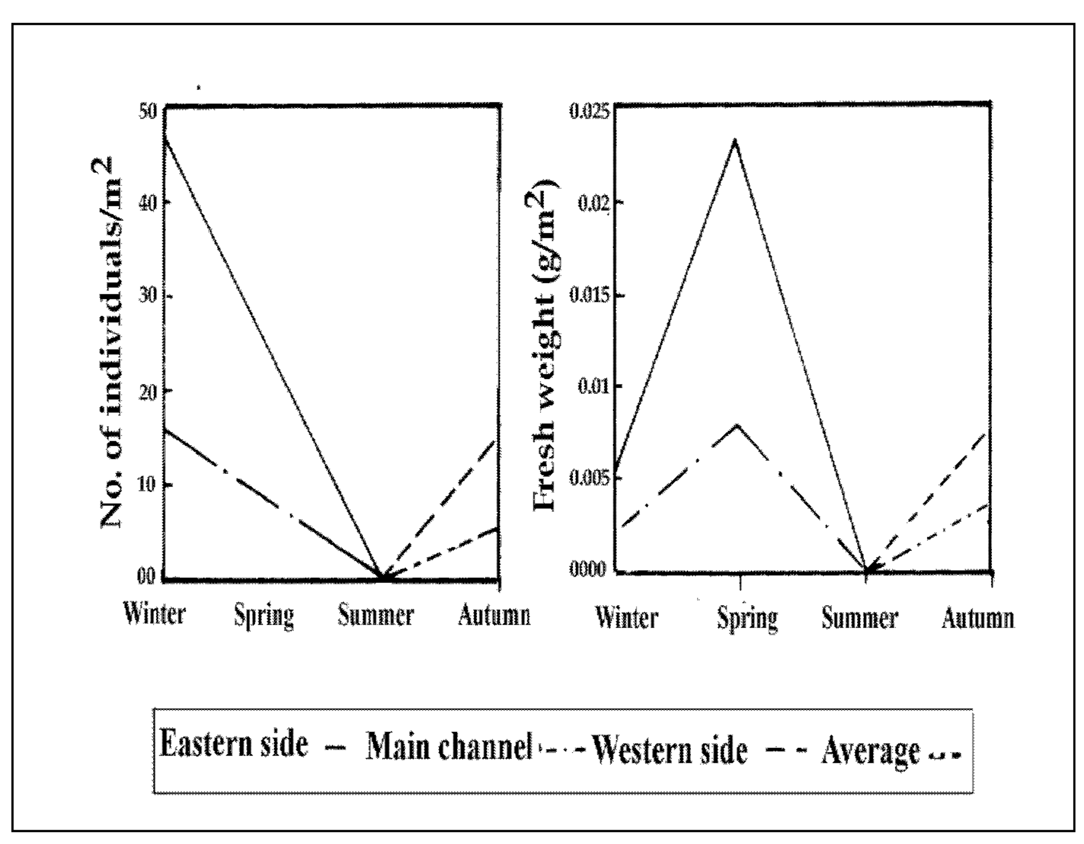


Fig. 114 **Seasonal variations of A: population density, and B: biomass of *Hydra vulgaris* in Lake Nasser during 1993 (Fishar 1995) [**For stations refer to Fig. 15**].**

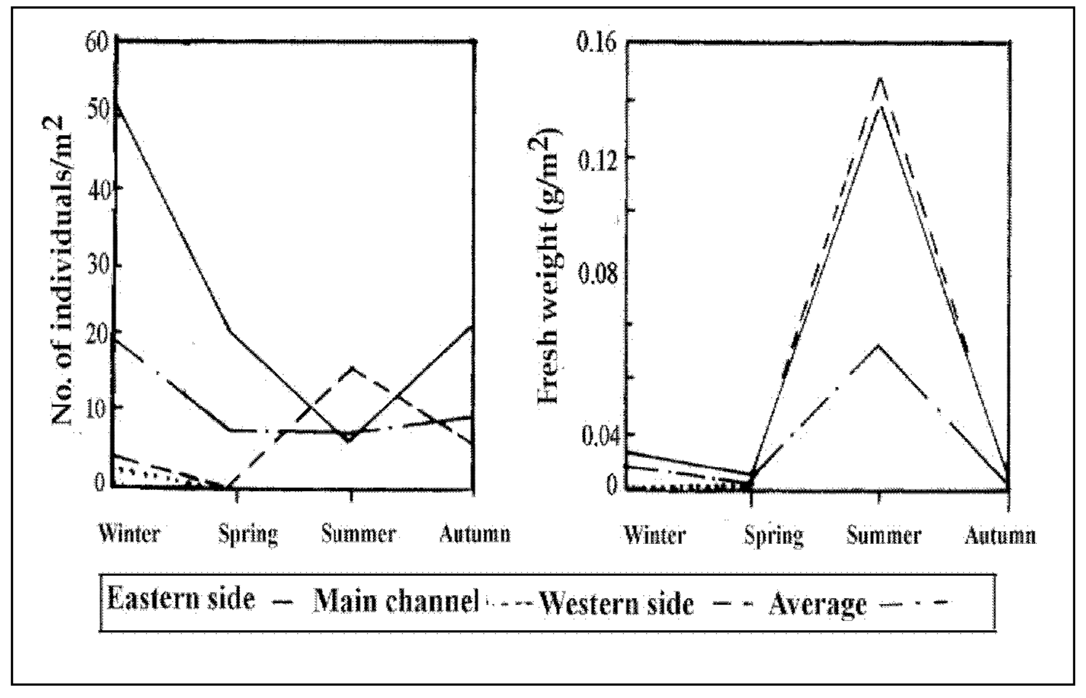


Fig. 115 **Seasonal variations of A: population density, and B: biomass of *Fredericella sultana* in Lake Nasser during 1993 (Fishar 1995) [**For stations refer to Fig. 15**].**

In the meantime, all bivalves already existing in the old river bed died during the stagnation period because of lack of oxygen (Entz 1976).

2.The second stage began with the final formation of the Lake and ended with the ending of the major African drought (1988). During this stage, about 30 benthic species were recorded (Anon. 1979, Elewa 1987b and Iskaros 1988); some previously recorded species such as *Potamonautes niloticus* disappeared.

3.The third stage extended from 1989 to 1993. In spite of the decline in the number of insects during this stage, the number of species constituted the benthic invertebrate community, further increased to 59 species, belonging to 4 Phyla.

CONCLUSIONS

Lake Nasser is very rich in **zooplankton,** including 79 species belonging to 4 major groups, with an annual density ranging from 233,900 to 562,100 ind./m^3 in the southern region of Lake Nasser and from 52,900 to 156,400 ind./m^3 in the northern region. The southern region of Lake Nasser is richer in zooplankton than the northern. From July to December 1990, the zooplankton wet weight ranged from 210 to 1940 and from 50 to 980 mg/m,^{3} collected from the southern and northern regions respectively. The highest number of zooplankton organisms (562,100 ind./m^3) was recorded at Abu Simbel in the southern region. The great abundance of zooplankton organisms in the southern region is attributed to high productivity of phytoplankton, since there is a high positive correlation between the number of zooplankton organisms and concentration of chlorophyll *a.*

The major zooplanktonic groups in Lake Nasser are Copepoda, Cladocera and Rotifera. There are variations in the percentage composition of the major planktonic species seasonally and regionally. Zooplankton numbers are more abundant at 5 to 10 m depth than at any other depth, except at Kalabsha station, where the highest number of zooplankton organisms was recorded at 15 m depth. There is a parallelism in number of zooplankton and mean value of chlorophyll *a* concentrations. Areas with high chlorophyll *a* concentrations (e.g. Korosko region) contain the highest number of zooplankton individuals (90 ind./l), as compared with the other areas as in Khor El Ramla (29 ind./l) corresponding to chlorophyll *a* values 9.1 and 2.9 mg/m^3.

High zooplankton density was recorded during the cold season (winter); while the lowest one was found during the hot season (summer). In winter, copepods, mainly nauplii, are most abundant (68.5%), followed by cladocerans (18.9%) and rotifers (12.7%).

Khors are richer in zooplankton density than the main channel, being nearly twice as that of the latter. In khors at least 34 zooplankton species were recorded, mainly copepods, cladocerans and rotifers. The littoral zone of khors has a sustainable standing stock of zooplankton all year round, with a maximum in winter and a minimum in summer, increasing in autumn and almost doubled in winter and spring. The highest standing crop is recorded at 5 m depth, and the lowest one at 20 m depth.

From the various studies on **benthic fauna** of Lake Nasser (Entz 1976, Latif 1984, Elewa 1987, Iskaros 1988, 1993, Fishar 1995) it is concluded that :

The number of recorded species is 59 belonging to 4 major groups and 9 classes, dominated by insects (29 species), followed by molluscs (19 species); oligochaete annelids and crustaceans each 4 species; and Hirudinea, Hydrozoa and Bryozoa each represented by one species. While Iskaros (1988, 1993) recorded 40 species, Fishar (1995) found 37 species. Nineteen species previously recorded by Iskaros (1988, 1993) were not included in Fishar's (1995) list of benthic fauna. The latter author recorded 13 species for the first time (Table 74).

Annelids and insects constitute the most common benthos with an average of 38.7 and 31.9% of all benthos. As to the total biomass, molluscs constitute the highest biomass in both the eastern (43.3%) and western sides (47.7%) of the Lake. Oligochaete annelids, however rank first (90.4%) in the main channel. Hydrozoans and bryozoans are the lowest in biomass. The littoral zone is richer in number and biomass of zoobenthos, than in the main channel which harbours much less benthos either in number or biomas. The eastern side of the Lake is richer in benthos, both number and biomass, than the western side. Molluscs, in this region, constitute the highest biomass. Khors (both littoral and profoundal zones) are richer in benthos than the main channel.

Amada station (200 km south from the High Dam) is the richest area in its benthos, compared with both northern and southern regions. The most productive season for benthos is autumn, followed by spring and summer; winter is characterized by the low number and biomass of benthos.

Certain species which were previously recorded during the early stages of Lake Nasser i.e. *Potamonautes niloticus,* was recorded by Latif (1984b) but was not recorded in subsequent studies (Entz 1976, Iskaros 1988,1993, Fishar 1995).

A comparison between the benthic fauna of the Lake recorded by Iskaros (1993) and Fishar (1995) is given in Table 77.

Table 77 **Comparison between the benthic fauna (number, biomass) of Lake Nasser recorded by Iskaros (1993) and Fishar (1995).**

	Iskaros (1993)			Fishar (1995)		
No. of species	**40 (15 spp. are not recorded by Fishar)**			**39 (10 spp. are not recorded by Iskaros)**		
Locality and Density	**Lake Nasser**	**No. (ind./m²)**	**Biomass (g/m²)**	**Lake Nasser**	**No. (ind./m²)**	**Biomass (g/m²)**
	Littoral	2659	13.1	**Amada**	1326	7.040
	Profoundal	288	1.9	**Adindan**	331	1.672
	Khor Kalashaba			**Main channel**	556	3.192
	Littoral	10292	33.9	**Eastern side**	1027	lower
	Profoundal	908	4.0	**Western side**	887	higher
				Average	823	4.776

Seasonal variations in number of organisms in Lake Nasser (ind./m²).

Site	Winter	Spring	Summer	Autumn
Western side	876	991	678	--
Eastern side	--	1038	960	1460
Main channel	--	2379	774	536
Average	610	815	804	1013

(--) not recorded

Chapter 7
Fish Species Diversity and Fish Biology

FISH SPECIES DIVERSITY

Entz (1976) and Latif (1984a) divided the High Dam Lake (i.e. Lake Nasser and Lake Nubia) into three sections :

1. Northern section (about 250 km from High Dam), extending southwards from High Dam to Amada or Tushka, is lacustrine.

2. Middle section (southern part of Lake Nasser from Tushka to Daweishat) is semiriverine during the flood season, and lacustrine during the other seasons.

3. Southern section, extending from Daweishat to Akasha in Lake Nubia, is riverine all year round.

Therefore, it can be said that Lake Nasser is almost lacustrine except in its southern part (about 50 km in length), which has riverine characteristics during the flood season. The Lake is eutrophic in some areas (khors), while it is mesotrophic to oligotrophic in the main channel (about 80% of the Lake area). Such characteristics of the Lake affect the fish species diversity which used to be riverine, leading to the dominance of lacustrine fish.

The surface area as well as the volume of water suitable for fish in the khors vary very much due to changing of water level. Khors or flooded flat areas are very different in their characteristics as fish habitats. Thus, it is worthy to know all the changes in surface and volume of water in these areas at different water levels. This knowledge is of great interest for fish stock assessment as well as for the fishery itself. The length of the shoreline and its slope are important for the development of periphyton and littoral fauna, which affect greatly the distribution of tilapiine spp., the most economic and important group of fish, especially abundant on sandy areas. The distribution

of the benthic fish food organisms is also affected by the morphology of the Lake. Oligochaetes are important fish food organisms and are mainly restricted to certain areas. Chironomids are most abundant in shallow water (5-10 m deep). Periphyton and phytoplankton are mainly restricted to the upper 2-4 m layer. During June and July, i.e., the period of fast decreasing water level, the periphyton almost disappears from the shore, being transferred into localities above the water level forming sometimes real crusts on the dry shore there. This is especially the case in flat areas, where a decrease of 3-4 m in water level causes the regression of lake water for 5-10 km distance (e.g. in Khor Kalabsha). During the new fast increase of the water level, at the beginning of the flood, there is no time for dense periphyton development. The new green belt of periphyton is observed again only in December or January.

The distribution of zooplankton is mainly affected by oxygen conditions. Because of the depth restrictions during the stagnation period associated with lack of oxygen in the hypolimnion, its amount is affected by the volume of the upper water layers.

Aquatic snails are very abundant on rocky areas, and almost completely absent from flat sandy shores. Thus, the distribution of the vector organisms of Bilharzia is more promoted on rocky than in sandy areas. Generally, the increase of the water level will increase the surface areas and the volume of the shallow water zones not only in absolute values but simultaneously their proportion, as compared with the total surface area of the Lake. Therefore, the uppermost water level plays the most important role in the productivity of the Lake. In other words, increasing water level is accompanied by an increase in the productivity of the Lake. Also, sedimentation of fertile mud especially within the southern region of Lake Nasser causes an increase in Lake productivity.

Generally, the fish species of new impoundments as Lake Nasser were known in the original water where the reservoir is created. However, the response of the "riverine" species to the new environment is different and this results in marked differences in their relative abundance with lacustrine conditions. In the early years, mormyrids disappeared from Lake Kainji, but fish of the genus *Citharinus* became the most important and predatory fish and cichlids increased (Lelek & El-Zarka, 1973).

In Lake Nasser, the 57 fish species recorded since 1964 (Table 78) belong to 16 families: Protopteridae, Polypteridae, Characidae, Citharinidae, Distichodontidae, Mormyridae, Gymnarchidae, Cyprinidae, Clariidae, Bagridae, Shilbeidae, Mochokidae, Malapteruridae, Cichlidae, Centropomidae and Tetraodontidae (Latif 1974a). Some fish species are extremely rare. For

example, only one specimen of either *Protopterus aethiopicus* or *Polypterus bichir* was caught. Furthermore, along the course of impoundment, some other species became less common, while others behaved differently. For example, *Chelaethiops bibie* and *Leptocypris* (*Barilius) niloticus* were common in the southern region of the Lake in 1970, but at present they are infrequent. Latif (1974a) pointed out that *Eutropius niloticus, Schilbe uranoscopus, S. mystes, Alestes dentex, A. baremoze, Mormyrus, Labeo* spp. and *Barbus* spp. were more frequent in Lake Nubia than in Lake Nasser. The reverse is true for *Sarotherodon galilaeus, Oreochromis niloticus, Hydrocynus forskalii, Brycinus nurse* and *Bagrus* spp. Again *Schilbe* spp. are more frequent in the southern part of Lake Nubia except during the flood, when these species become common in flooded areas. On the other hand, *Alestes baremoze* and *A. dentex* are repelled by these waters and thus become more common in the southern part of Lake Nasser ahead of the flood than elsewhere in other times. However, *A. baremoze* migrates upstream for spawning in Lake Nubia (Rashid 1977). Similar migration from natural lakes to connecting rivers for spawning have been observed elsewhere (Durand & Loubens 1971, Hopson 1972). Nowadays the most common fish species are 23 (Table, 102). During recent years specimens of *Oreochromis aureus* and *Tilapia zillii* were recorded from the Lake.

In recent years, the Lake fisheries depend only upon a limited number of species, which are given in the order of importance : *Sarotherodon galilaeus, Oreochromis niloticus, Hydrocynus forskalii, Brycinus nurse, Alestes dentex, A. baremoze, Lates niloticus, Bagrus bajad, B. docmack, Synodontis serratus, Barbus bynni, Labeo horie, L. coubie, L. niloticus* and *Eutropius niloticus. Sarotherodon galilaeus* and *Oreochromis niloticus* adapted well to the new conditions in the Lake. The most common open-water species are *Alestes* spp., *Hydrocynus forskalii* and *Eutropius niloticus. Brycinus nurse* and *H. forskalii* are also abundant in inshore waters as are *Lates niloticus, Oreochromis niloticus* and *Sarotherodon galilaeus.*

Today, only two fish species : *Sarotherodon galilaeus* and *Oreochromis niloticus* dominate the fish catch from the Lake, contributing about 90-95% of the total fish production from Lake Nasser. Therefore, *Tilapia* species have proved to be very well adapted and suited to the erratic ecosystem of the Lake. Others are contemporary commercial fish species (i.e. *Hydrocynus* spp., *Synodontis* spp., *Bagrus* spp., *Lates niloticus* and *Brycinus nurse*).

Thus, the species diversity has declined and some species are now restricted only to the southern region of the Lake, while others have vanished completely from it.

The khors (85 major) of Lake Nasser provide the most important habitat for fish to breed and feed, because of their shallowness and abundance of

phytoplankton. The open and deep waters of the Lake are relatively poor in fishes inspite of the fact that they are rich (to a certain extent) in plankton.

Table 78 **Fishes recorded in Lake Nasser (Latif 1974a). [Plates 34 –49]**

Family	Species	Local Name	
Protopteridae	*Protopterus aethiopicus*	Dabib El-Hout	دبيب الحوت
Polypteridae	*Polypterus bichir*	Abu-Bichir	أبو بشير
Mormyridae	*Mormyrops anguilloides*	Gamhour	جمهور
	Petrocephalus bane bane	Gelmaya, Arminya	قلميه
	Pollimyrus isidori	Anooma	أنومـــة
	Gnathonemus cyprinoides	Um-Shafika	أم شفيقـــه
	Mormyrus kannume	Um-Bowez	أم بويـــز
	Mormyrus caschive	Boweza	بويـــزه
	Hyperopisus bebe bebe	Kalamya-Babeh	قلميا – بيبه
Gymnarchidae	*Gymnarchus niloticus*	Rayah Niliah	ريه نيليـــه
Characidae	*Hydrocynus forskalii*	Kalb El-Samak	كلب السمك
	Hydrocynus vittatus	Kalb El-Samak	كلب السمك
	Hydrocynus brevis	Kalb El-Samak	كلب السمك
	Alestes dentex	Rayah	ريـــــــه
	Alestes baremoze	Rayah	ريـــــه
	Brycinus nurse	Sardina	سردينه
Distichodontidae	*Distichodus niloticus*	Lessan El-Bagar	لسان البقر
Citharinidae	*Citharinus citharus*	Kamara	قمـــره
	Citharinus latus	Kamara	قمـــره
Cyprinidae	*Chelaethiops bibie*	Bebe	بيبيـــه
	Labeo victorianus	Lebeis Hagari	لبيس حجر
	Labeo niloticus	Lebeis Nili (abyad)	لبيس نيلى
	Labeo coubie	Lebeis Aswad	لبيس أسود
	Labeo horie	Lebeis Aswad	لبيس أسود
	Garra dembeensis	Abu-Kors	أبو قرص
	Barbus bynni	Benni	بنى
	Barbus werneri	Benni	بنى
	Barbus anema	Benni	بنى
	Barbus perince	Benni	بنى
	Barbus neglectus	Benni	بنى
	Raiamas loati	Morgan loti	مرجان لوتى
	Leptocypris niloticus	Bebee–Margan Nili	مرجان نيلى
Clariidae	*Clarias anguillaris*	Hout, Karmout	حوت قرمـــوط
	Clarias gariepinus	Hout, Karmout	حوت قرمـــوط
	Heterobranchus longifilis	Hout, Karmout	حوت قرمـــوط
	Heterobranchus bidorsalis	Hout, Karmout	حوت قرمـــوط
Schilbeidae	*Schilbe (Eutropius) niloticus*	Schilba	شلبه
	Schilbe (Schilbe) mystus	Schilba	شلبه
	Schilbe (Schilbe)uranoscopus	Schilba-Arabi	شلبه عربى
	Siluranodon auritus	Schilba	شلبه
Bagridae	*Bagrus bajad*	Bayad	بياض
	Bagrus docmak	Docmack	دقماق
	Chrysichthys auratus	Gurgar	جرجور

	Chrysichthys rueppelli	Gurgar Schami	جرجور شامى
	Clarotes laticeps	Abu-Meseka	أبو ميسيكه
	Auchenoglanis biscutatus	Halouf	حلوف

Table 78 **(cont.)**

	Auchenoglanis occidentalis	Halouf	حلوف
Mochokidae	*Synodontis schall*	Schall	شال
	Synodontis serratus	Schall	شال
	Synodontis clarias	Schall	شال
	Mochocus niloticus	Mekawkas Nili	مقوقس نيلى
	Chiloglanis niloticus	Kiloglans	كيلوجلانس
Malapteruridae	*Malapterurus electricus*	Rahaad	رعاد
Cichlidae	*Sarotherodon galilaeus*	Bolti Galili	بلطى جاليلى
	Oreochromis niloticus	Bolti Nili	بلطى نيلى
	*Oreochromis aureus**	Bolti Azrak	بلطى أزرق حسانى
	Tilapia zillii	Bolti Akhadar	بلطى أخضر
Centropomidae	*Lates niloticus*	Samous, Ishr-Bayad	ساموس
Tetraodontidae	*Tetraodon linneatus*	Fahaka	فهقة

*** This species was recently recorded in 1996 (SECSF).**

BIOLOGY OF IMPORTANT FISH SPECIES

The study of the biology of Lake Nasser fishes was carried out by various investigators: (Latif 1974b, Latif & Rashid 1972, 1983, Latif & Abdel-Azim 1973b, Abdel-Azim 1974, 1991a and b, Latif *et al.* 1979, Talat 1979, Khallaf & Latif 1987, Latif & Khallaf 1987, Yamaguchi *et al.* 1990, Agyapi 1992a, Mohamed, I. 1992b, Mohamed, S. 1994, Adam 1994, 1995a & b, 1996a & b, Mekkawy *et al.* 1994, Mekkawy & Mohamed 1995, Shenouda *et al.* 1995, Mekkawy, 1996, who studied *Oreochromis niltoicus* and *Sarotherodon galilaeus* - Cichlidae); (Latif 1974b, Latif *et al.*1979, Massoud *et al.* 1985, who studied *Hydrocynus forskalii* - Characidae); (Latif 1974b, Rashid, 1977, Latif *et al.* 1979, who studied *Alestes* spp. - Characidae); (Latif 1974b, Latif & Khallaf 1974a, El-Etreby 1976,1982, Latif *et al.* 1979, who studied Nile perch *Lates niloticus* - Centropomidae); (Latif 1974b, Latif *et al.* 1979, 1984a-c, Abbas 1982, 1986, Mahmoud & Mekkawy 1991, Mekkawy & Mahmoud 1992a, who studied Synodontidae); (Latif 1974b, Khallaf 1977, Latif *et al.* 1979, Latif & Khallaf 1996, who studied Schilbeidae); (Latif 1974b, Latif *et al.* 1979, Khallaf 1985, 1988; Mekkawy 1997 a and b, Shenouda *et al.* 1994a and b, who studied Bagridae); (Latif 1974b, Latif *et al.* 1979, Abdel-Azim 1982, Mekkawy & Mahmoud 1992b, Shenouda 1992 who studied Cyprinidae) and Latif 1974b, Latif *et al.* 1979, El-Etreby 1985, Mekkawy 1990, 1996, Aly 1993, who studied Mormyridae).

When referring to the fisheries of Lake Nasser it is inevitable to mention some of the relevant aspects on the biology of the most important fish species which may be the basis of development and management of lake fisheries.

1. FOOD AND FEEDING HABITS

The work of Latif *et al.* (1979) was the only complete study on the food and feeding habits of the main fish species inhabiting Lake Nasser, hence reference to the results of their work will be reviewed together with recent studies.

Analysis of gut contents of different species of fishes is considered one of the most important methods to estimate the selectivity of natural food and the ecological niche of various species. Furthermore, food analysis is used to determine the natural diet of species concerned and the extent of its availability in its natural habitat. Lake Nasser is rich in various food items including: periphyton, phytoplankton, zooplankton, insect larvae mainly chironomids and molluscs (gastropods and bivalves), oligochaetes, freshwater shrimps and many others). According to their feeding habits fish species inhabiting Lake Nasser can be divided into :

1. Periphyton-plankton feeders : mainly *O. niloticus* and *S. galilaeus*

2. Zooplankton-insect feeders : *Alestes* spp.

3. Omnivores : *Labeo* spp., *Barbus* spp. *Synodontis* sp., schilbeids and mormyrids.

4. Carnivores (piscivores): *Lates niloticus, Hydrocynus* spp., *Bagrus* spp. *Clarias* spp. and *Heterobranchus* spp.

The major food items and their percentage occurrence in the commercial fish species from Lake Nasser are shown in Table 79 (p. 238).

Oreochromis niloticus. Before the construction of Aswan High Dam and during the early years of filling, this species was the major tilapiine sp. contributing a high percentage of the total yield. *Oreochromis niloticus* feeds mainly on plant material: Cyanophyta (*Oscillatoria, Lyngbya, Merismopedia, Dactyloccopsis, Anabaena, Microcystis* spp. etc.) composing 30% of the total food and occurred in 90% of the fish (Latif *et al.* 1979). Diatoms (*Melosira, Navicula, Cymbella, Synedra* spp. etc.) formed about 25% and were recorded in 80% of the guts of examined fish. Chlorophyta (*Cosmarium, Scendesmus, Crucigenia, Volvox* spp. etc.) comprised 22% of the diet and were found in 80% of the guts of fish. The latter authors pointed out that higher plants formed only 7% and occurred in 40% of the fish. Copepods (e.g. *Cyclops* spp.) and Cladocera (e.g. *Daphnia* and *Bosmina* spp.) formed 15% of the food and were found in 20% of the fish. Also, the fish were seen grazing on periphytes (Latif *et al.* 1979). Abdel-Azim (1991b) found that the percentage composition of copepods, rotifers and cladocerans eaten by *O. niloticus* at different localities of Lake Nasser during early spring (1988) were 4.6, 0.05 and 1.25% respectively while during late summer it was 3.89; 0.21 and 1.88%. When considering the length of *O. niloticus* Abdel-Azim (1991a) pointed out that zooplankton constituted about 4.0, 6.9 and 10.4% of the stomach contents of lengths 3.9-9, 9.1-20 and 20.1-45 cm respectively. The food of fry of *O. niloticus* and *S. galilaeus* consisted mainly of nauplius larvae, copepodite stages of Copepoda, cladocerans and rotifers, in addition to other food items (Abdel-Mageed 1995). Mohamed, I. (1992b) mentioned that *O. niloticus* subsists mainly on Dinophyceae (*Peridinium* and *Ceratium* spp.), diatoms (*Melosira, Navicula, Cymbella* spp. etc.), blue-green algae (*Merismopedia,*

Lyngbya and Microcystis spp.), green algae (*Scendesmus and Staurastrum* spp.) (Table 80).

Sarotherodon galilaeus. The gut contents of *S. galilaeus* included more plant food than animal material. Latif *et al.* (1979) mentioned that diatoms and Chlorophytes were common in 90% of the fish, and they formed 40 % of the diet, while cyanophytes were less frequent and were found in small quantities (15%). Zooplankton organisms, cladocerans (*Daphnia* and *Bosmina* spp.) were rarely observed in the guts. Periphytes composed 40% of the food and were recorded in 25% of the guts of fish examined. Zooplankton (mainly copepods and cladocerans) comprised only 5% of the food and appeared in 15% of the fish (Latif *et al.* 1979). It is worth mentioning that *S. galilaeus* is nowadays the major tilapiine species in the total annual fish production (i.e. more than 60% of the annual catch).

Brycinus nurse. The percentage occurrence and composition of various food items in the guts of *B. nurse* (Figs. 116 and 117) indicates that insect larvae constitute the major food item (49%), followed by gastropods (25%), cladocerans (17%), copepods (9%), decapods (0.2%) and others (0.2%) (Latif *et al.* 1979).

Alestes baremoze. This species feeds mainly on insects which constitute 41.4% of the gut contents followed by cladocerans (21.9%), phytoplankton (18.5%), gastropods (9.8%) and copepods (8.4%) (Latif *et al.* 1979 - Fig. 118).

Schilbe (Eutropius) niloticus. This species feeds mainly on insect larvae (Chironomidae) and to a lesser extent on Odonata, fishes, water beetles. Worms, freshwater shrimps, bivalves were much less frequent (Latif *et al.* 1979). Fishes more than 23 cm long may feed mainly on other fish species e.g. *Alestes* spp.

Schilbe uranoscopus. Latif *et al.* (1979) mentioned that the gut contents of *Schilbe uranoscopus* included small fishes (*Hydrocynus* spp. and *Alestes* spp.), chironomid larvae and placopteran nymphs. *Cyclops* and *Daphnia* were accidentally ingested, apparently as the fish secures its food from surface waters.

Synodontis spp. They are omnivorous fish, utilizing animal food (fish, worms, molluscs and insects) and some food of plant origin taken incidentally when securing the food from the bottom or the crevices between stones. Both phyto- and zooplankton are occasionally taken by the fish while scooping its insect diet (Latif *et al.* 1979).

***Labeo* and *Barbus* spp.** Latif *et al.* (1979) mentioned that *Labeo* and *Barbus* species are omnivorous, feeding mainly on diatoms, cyanophytes, worms and plant material.On analysing the gut contents of *Labeo* spp. (*Labeo horie, L. coubie, L. niloticus*) and *Barbus bynni,* Abdel-Azim (1982) found that they contain inorganic particles (sand and mud), aquatic plants (macrophytes and epiphytes), phytoplankton (diatoms, cyanophytes and chlorophytes), worms

and insect larvae. This food pattern denotes that the above-mentioned

Fig. 116 **Percentage occurrence of different food items in the guts of *Brycinus nurse* (Latif *et al.* 1979).**

Fig. 117 **Percentage composition of different food items in the guts of *Brycinus nurse* (Latif *et al.* 1979).**

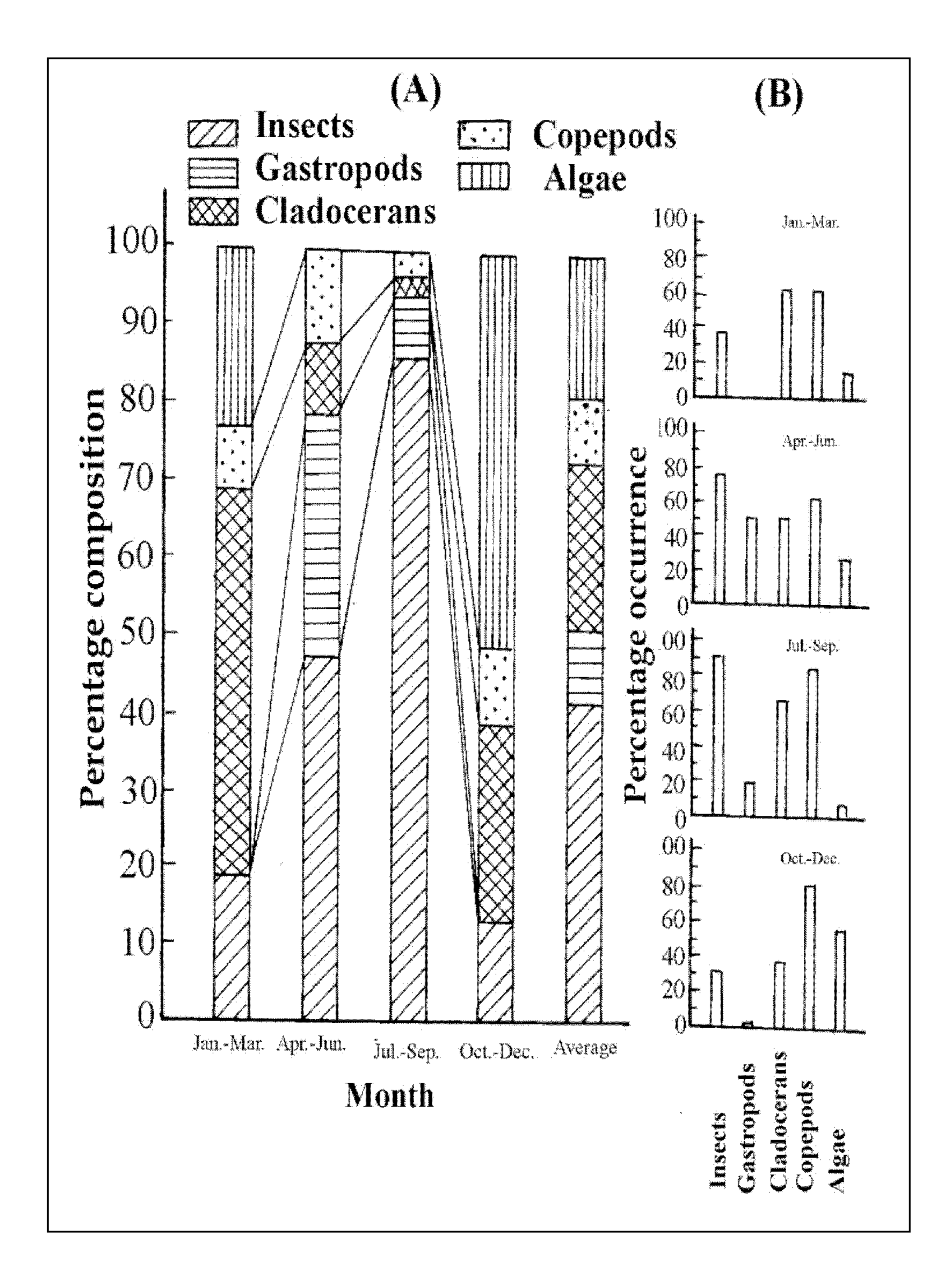


Fig. 118 **A: Percentage volume of different food items in the guts of *Alestes baremoze*, B: Frequency occurrence of different food items in the guts of *A. baremoze* (Latif *et al*. 1979).**

Table 79 **Major food items and their percentage occurrence for various fish species in Lake Nasser.**

Species	Major food items and their percentage occurrence
Oreochromis niloticus	Cyanophyta (90%); diatoms (80%); Chlorophyta (80%); copepods and cladocerans (20%); higher plants (40%) and periphyton.
Sarotherodon galilaeus	Diatoms (90%); Chlorophyta (90%); Cyanophyta (15%); zooplankton (15%); and periphyton (25%).
Brycinus nurse	Insect larvae; gastropods; cladocerans; copepods and decapods.
Alestes baremoze	Insects, cladocerans, phytoplankton, gastropods and copepods.
Schilbe (Eutropius) niloticus	Insect larvae (chironomids, Odonata); water beetles; shrimps, worms, fishes and bivalves.
Schilbe uranoscopus	Small fish; chironomid larvae; *Cyclops* and *Daphnia*.
***Synodontis* spp.**	Omnivorous: insects; worms; fish; molluscs; food of plant origin, phyto- and zooplankton.
***Labeo* spp.**	Omnivorous mainly Chlorophyceae; Cyanobacteria; diatoms; cyanophytes; worms; plant material etc.
***Mormyrus* spp.**	Omnivorous: aquatic insects, larvae and pupae of chironomids, nymphs of Odonata, Trichoptera larvae, shrimps, detritus, aquatic plants and diatoms.
Hydrocynus forskalii	Fishes (64.9%); insects (26.1%) shrimps (9%), fishes increase with increase of length.
Lates niloticus	Fishes, insects; shrimps (vary with fish length). Large fish feed mainly on fish, *Alestes* spp. tilapias, Nile perch.
***Bagrus* spp.**	Fishes (mainly tilapias, *Alestes*, *Synodontis*, *Mormyrus*, *Labeo*, *Barbus* and *Schilbe* spp.); insect larvae, molluscs and shrimps.
***Clarias* and *Heterobranchus* spp.**	Omnivorous bottom feeders; food of animal origin (insects, fishes etc.) and plant material.

***Table 80* Gut contents of *Oreochromis niloticus* from Khor El Ramla (Mohamed, I. 1992b).**

Phytoplankton		Attached algae	Zooplankton
Chlorophyta	**Bacillariophyta**	**Chlorophyta**	**Cladocera**
Volvox spp.	*Cyclotella* spp.	*Cladophora* spp.	*Bosmina* spp.
Pediastrum spp.	*Synedra* spp.	*Oedogonium* spp.	*Diaphanosoma* spp.
Ankistrodesmus spp.	*Amphora* spp.	*Spirogyra* spp.	*Daphnia spp.*
Scendesmus spp.	*Cymbella* spp.	**Cyanophyta**	*Ceriodaphnia* spp.
Cosmarium spp.	*Cocconeis* spp.	*Oscillatoria* spp.	**Rotifera**
Coelastrum spp.	*Navicula* spp.	*Phormidium* spp.	*Keratella* spp.
Cyanophyta	*Diatoma* spp.	*Lyngbya* spp.	**Ostracoda**
Chroococcus spp.	**Pyrrophyta**	**Bacillariophyta**	*Cypris* spp.
Aphanocapsa spp.	*Peridinium* spp.	*Melosira* spp.	**Copepoda**
Microcystis spp.	*Ceratium* spp.		*Cyclops* spp.
Merismopedia spp.			

***Table 81* Occurrence and ratio of various food items in the guts of *Lates niloticus* according to different length groups (Shrimps = 100%) (Latif *et al. 1979*).**

Length group (cm)	Occurrence (Shrimps as base) %			Ratio		
	Shrimps	Insects	Fish	Shrimps	Insects	Fish
10-14.9	100	220	13.3	1	2.2	0.13
15-19.9	100	416.8	154.2	1	4.2	1.5
20-29.9	100	85	86.4	1	0.8	0.9
>30	100	29	85.4	1	0.3	0.8

fishes secure food materials from the bottom or among aquatic plants. The different food components generally occur at varying degrees in the different periods of the year (Abdel-Azim 1982). Abdel-Mageed (1995) found that the stomach contents of adult *Labeo* spp. contained chironomid larvae, nematode worms, copepods in addition to other food items.

***Mormyrus* spp.** These fishes feed on aquatic insects, freshwater shrimps, annelids and to a less extent fishes (Latif *et al.* 1979). Aly (1993) mentioned that *Mormyrus* spp. feed mainly on larvae and pupae of chironomids, nymphs of Odonata, Corixidae (water bugs), *Cardina nilotica,* larvae of Trichoptera, Cladocera, detritus particles, in addition to aquatic plants and diatoms.

Hydrocynus forskalii. This species is carnivorous feeding on fishes (% occurrence 64.9), insects (% occurrence 26.1) and freshwater shrimps (% occurrence 9.0) (Latif *et al.* 1979). The percentage occurrence of food items of *H. forskalii* varies according to different lengths and during different seasons. The percentage occurrence of

fishes increases progressively with length. Thus, fish more than 50 cm total length feed on fishes only (Fig. 119). Furthermore, the percentage occurrence of the various food items shows a remarkable change at the various seasons, which may be attributed to availability of the suitable food items (Fig. 119B).

Lates niloticus. *L. niloticus* is a predator, feeding mainly on fishes, freshwater shrimps and insects (Table 81 - Latif *et al.* 1979). The percentage occurrence of the various food items shows a remarkable variation with the length of fish (Table 81 and Figs. 120 and 121) compared with shrimps as food. Furthermore, the percentage occurrence of the various fish species in the gut contents indicates that *Alestes* spp. is the major food item, followed by catfishes, tilapias and Nile perch (Fig. 121).

***Bagrus bajad* and *B. docmak*.** *Bagrus* species are carnivorous, feeding mainly on fishes (*Tilapia, Alestes, Synodontis, Mormyrus, Labeo, Barbus, Eutropius* spp.), insect larvae, molluscs and freshwater shrimps. The percentage of each food item varies with the fish length which is probably taken as the fish secure the food from the bottom.

***Clarias gariepinus, Heterobranchus bidorsalis* and *H. longifilis*.** Catfishes are omnivorous bottom feeders. Their food consists mainly of animal origin (fishes, insects and molluscs) in addition to plant material (Latif *et al.* 1979).

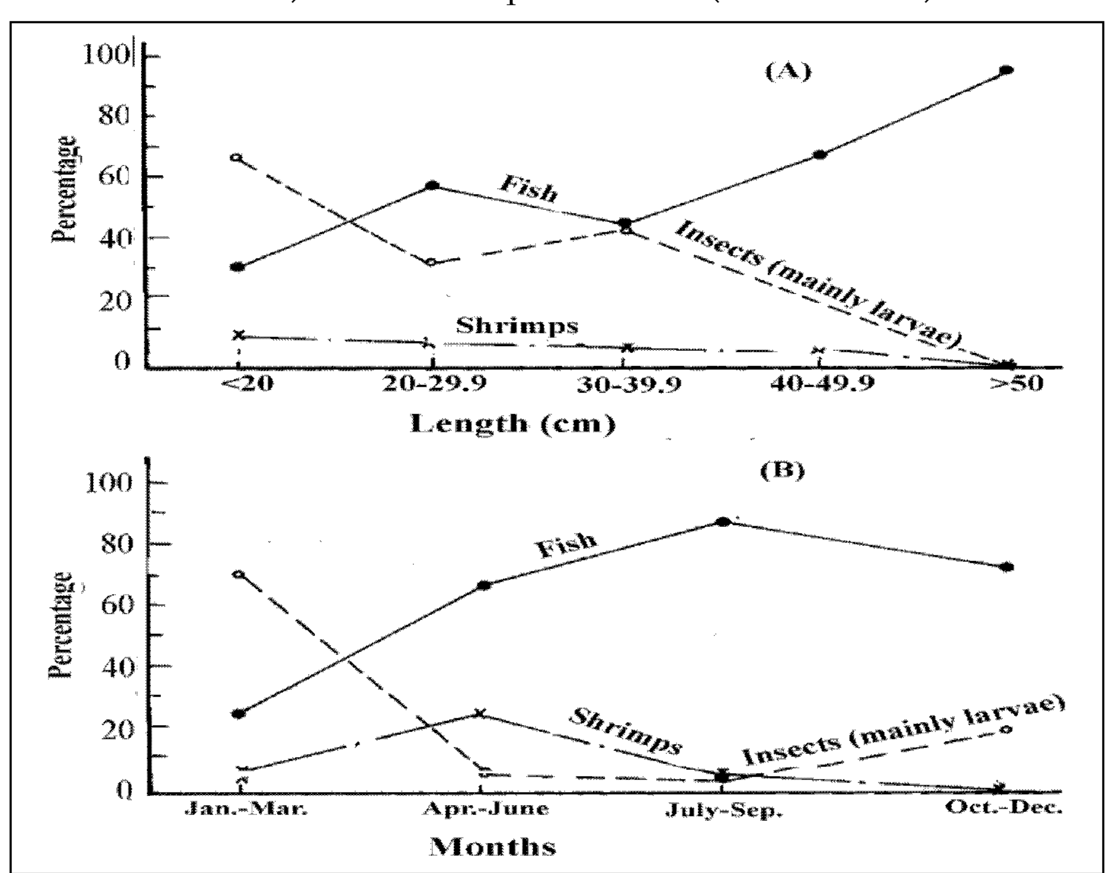


Fig. 119 **Frequency of fish with each food item in the guts of *Hydrocynus forskalii* according to A: length, B: different periods (Latif *et al.* 1979).**

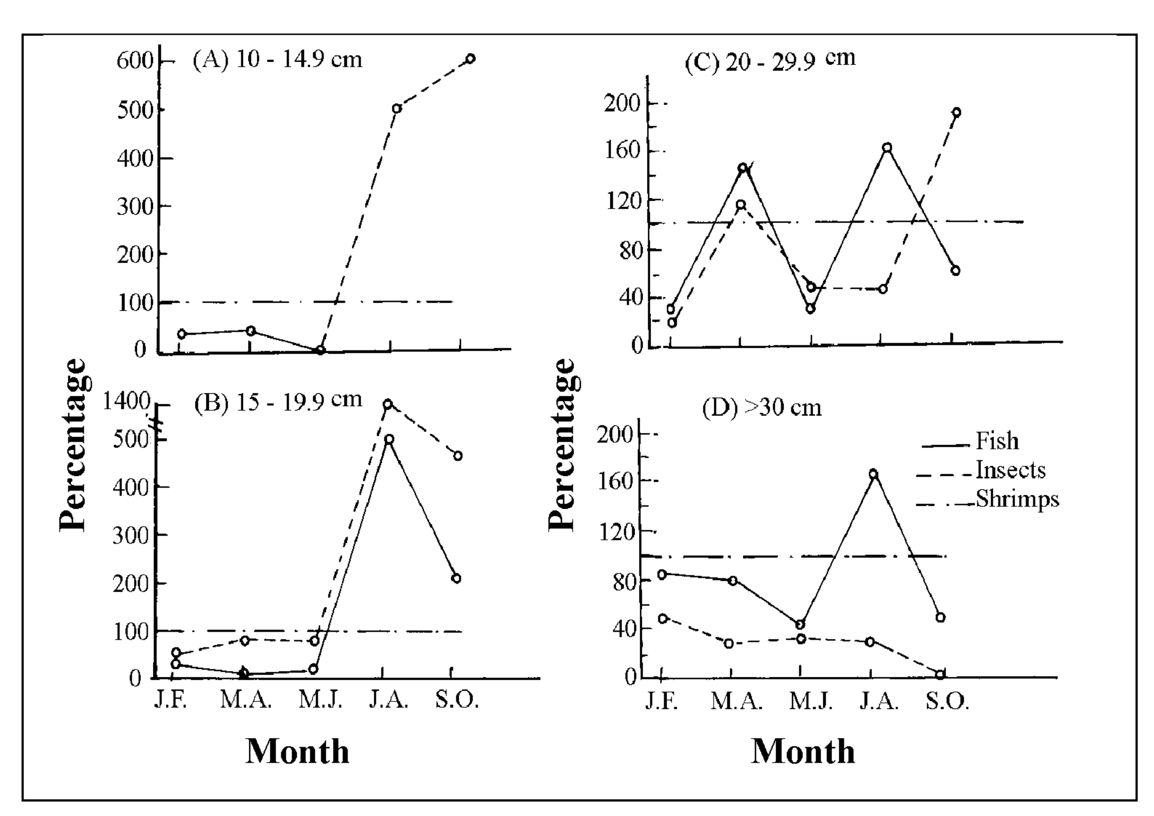


Fig. 120 **Bimonthly frequency occurrence of different food items in the guts of young and adult *Lates niloticus* (Latif *et al* 1979).**

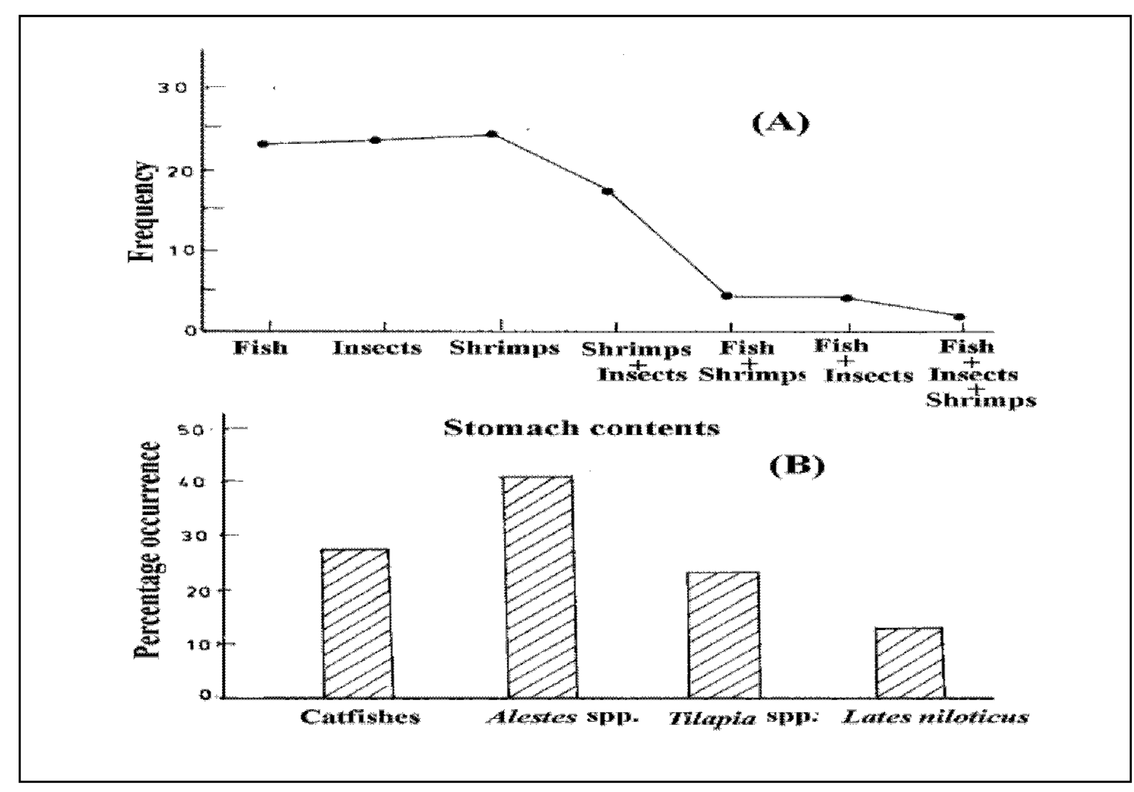


Fig. 121 **Food of *Lates niloticus*, A: frequency of different food items, B: percentage occurrence of different fish species in gut contents (Latif *et al.* 1979).**

2- AGE AND GROWTH

For the development and management of the fisheries of Lake Nasser a knowledge of the biological parameters of the various commercial fish species is of utmost importance. Among these parameters are the age, growth, length weight relationship as well as the calculated lengths and weights of the different age groups. Hence, in the present study reference will be given to the results of various investigators working on the biology of fish inhabiting Lake Nasser (Abdel-Azim 1974, Latif *et al.* 1979- 12 species, Agaypi (1992a) *Tilapia* species, Aly 1993 - mormyrid species, and Adam 1994 - *Tilapia* species).

Length-weight Relationship

Oreochromis niloticus (Fig. 122)

Log W = -1.6193 + 2.9723 Log. L. (1965) }
Log W = -1.4961 + 2.8773 Log. L. (1966) } Abdel-Azim (1974)
Log W = -1.6891 + 3.0230 Log. L. (1970) }
$W = 0.165 \times 10^{-2} L^{2.60}$ 1982 Agaypi (1992a)
LogW = -4.2343 + 2.9396 Log. L (1989/1990) Adam (1994)
$W = 2.466 \times 10^{-2} L^{2.9310}$ (1989/1990) Mekkawy *et al.* (1994)
$W = 0.0736 \times 10^{-2} L^{2.8422}$ (1996) SECSF (1996)

Sarotherodon galilaeus (Fig. 123)

Log W = -1.7899 + 3.1240 Log L. (1972/1973) Abdel-Azim (1974)
$W = 0.165 \times 10^{-2} L^{2.6}$ (1982) Agaypi (1992a)
Log W = -3.7929 + 2.7792 Log L. (1989/1990) Adam (1994)
$W = 3.145 \times 10^{-2} L^{2.8687}$ (1989/1990) Mekkawy & Mohamed (1995)
$W = 0.2534 \times 10^{-2} L^{2.4490}$ (1996) SECSF (1996)

Brycinus nurse
Log W = - 4.8230 + 3.0925 Log L. (SL in mm)

Alestes baremoze
Log W = - 1.9436 + 3.0702 Log L. (SL in cm)

Hydrocynus forskalii
Log W = - 2.0143 + 3.0644 Log L. (SL in cm)

Lates niloticus
Log W = - 4.3870 + 2.907 Log L. (SL in mm)

Eutropius niloticus
Log W = - 5.2825 + 3.1602 Log L. (SL in mm)

Labeo coubie
Log W = - 1.4130 + 2.9059 Log L. (SL in cm)

Labeo horie
Log W = - 1.3617 + 2.8661 Log L. (SL in cm)

Labeo niloticus
Log W = - 1.881 + 3.1472 Log L. (SL in cm)

Labeo forskalii
Log W = - 1.4661 + 2.8820 Log L. (SL in cm)

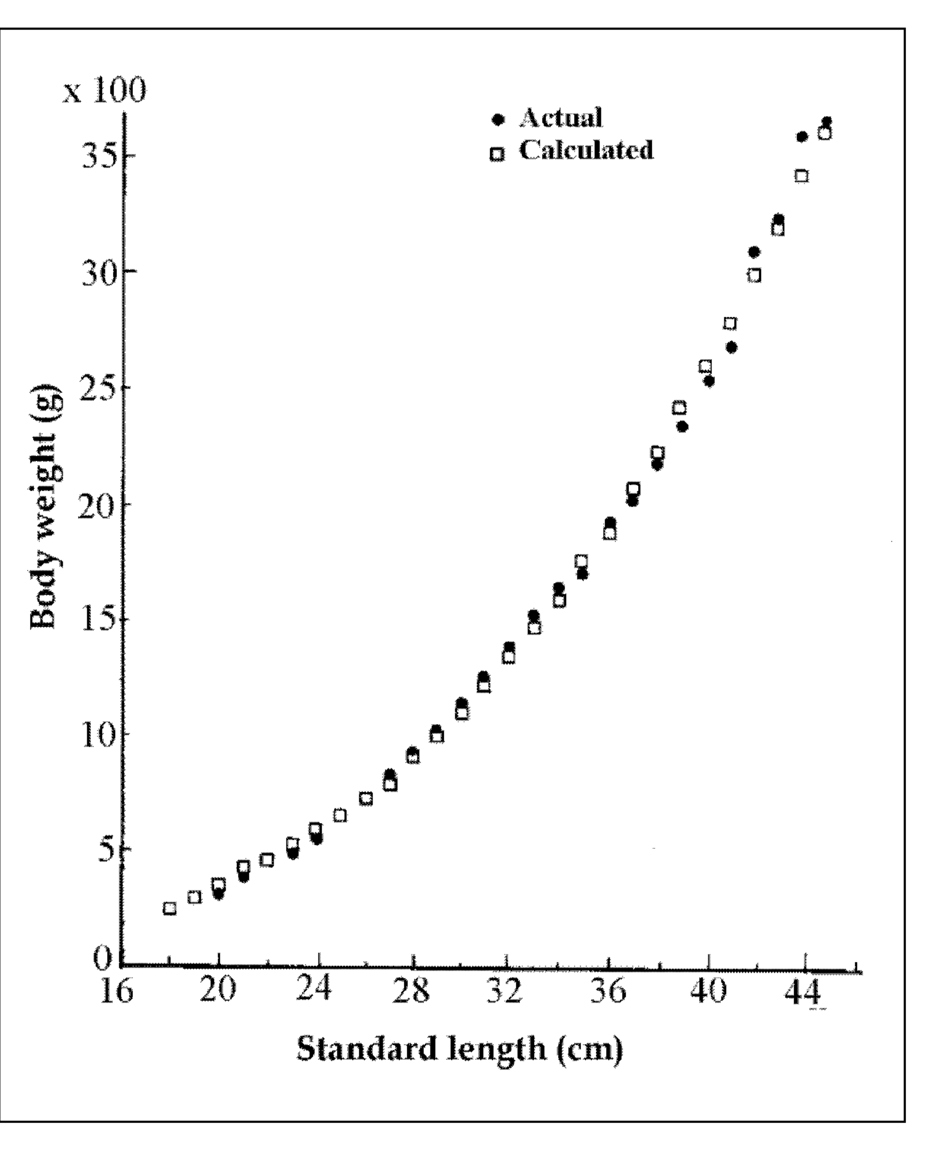


Fig. 122 **Length-weight relationship of *O.niloticus* (Adam 1994 and 1996b).**

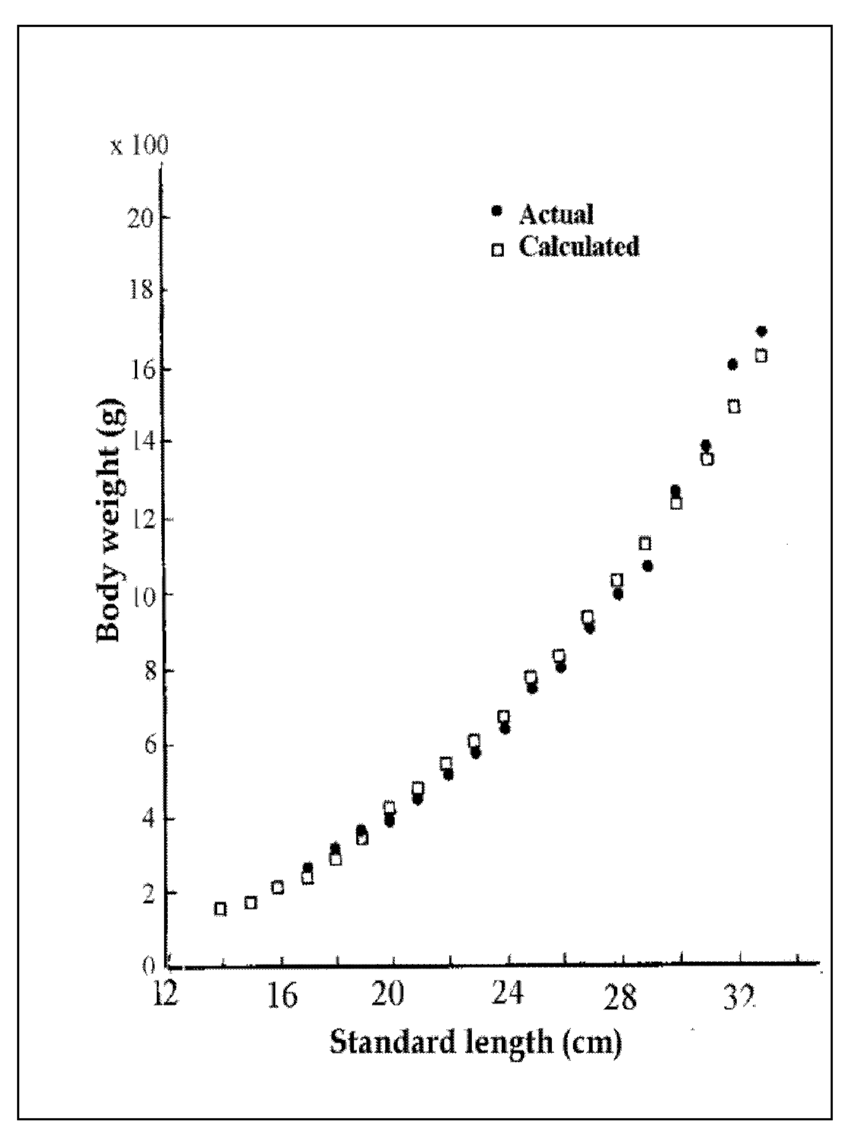


Fig. 123 **Length-weight relationship of *S. galilaeus* (Adam 1994).**

Log W = - 1.7230 + 3.0805 Log L. (SL in cm)

Bagrus docmak and ***Bagrus bajad*** (El-Badawy 1991)

Log W = - 4.4779 + 2.8802 Log L. for *Bagrus docmak.*

Log W = - 4.3332 + 2.7858 Log L. for *Bagrus bajad.*

The value of the exponent, being 2.88 and 2.78 for *B. docmak* and *B. bajad* respectively, shows that growth of these two species is allometric (Ricker 1975).

Mormyrus kannume (Aly 1993 - Fig. 124).

Log W = - 5.0332 + 3.0145 Log L.

Mormyrus caschive (Aly 1993 - Fig. 125).

Log W = - 4.83857 + 2.9359 Log L.

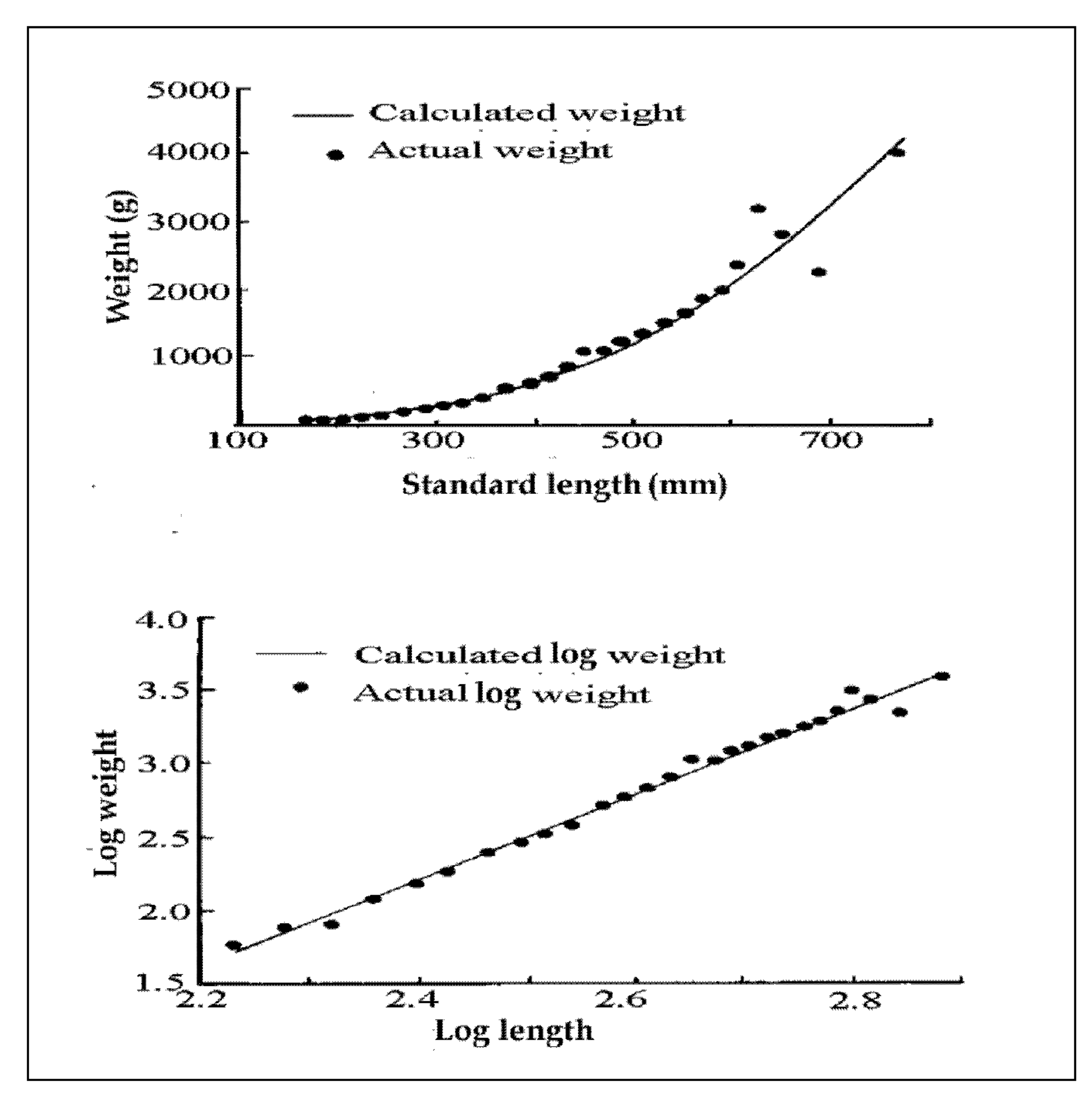


Fig. 124 **Length-weight relationship of *Mormyrus kannume* from Lake Nasser (Aly 1993).**

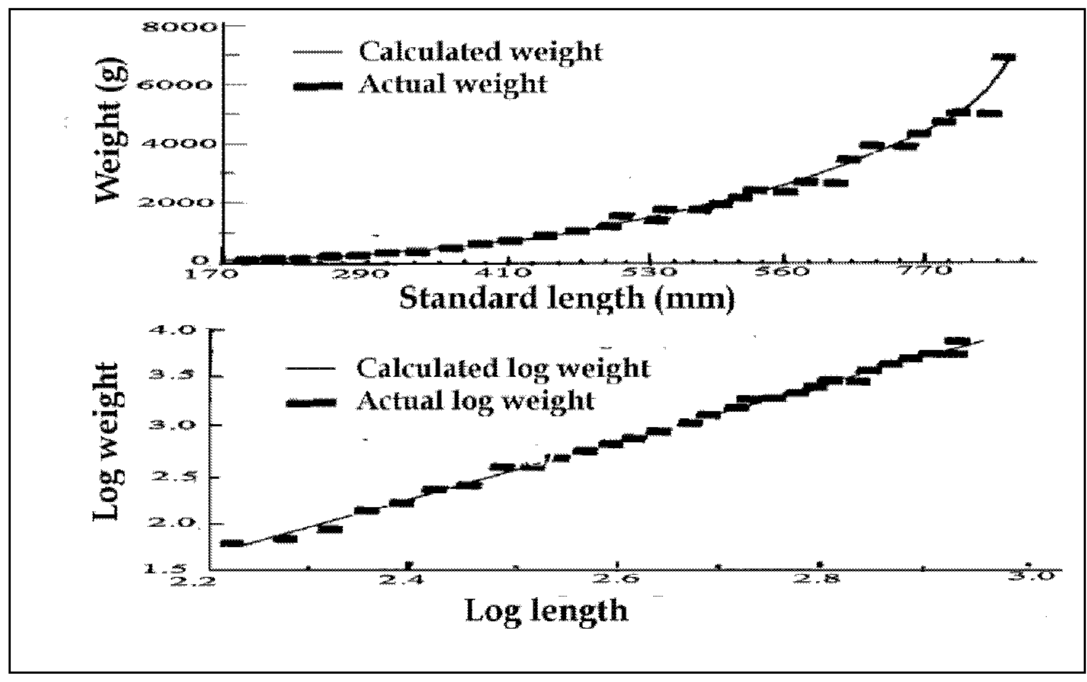


Fig. 125 **Length-weight relationship of** ***Mormyrus caschive*** **(Aly 1993).**

Condition factor

Adam (1994 and 1996b) calculated the condition factor of *O. niloticus* and *S. galilaeus* in Lake Nasser (Fig. 126). It is obvious that the condition factor of *O. niloticus* for all length groups ranged between 3.90 and 4.45. The values of condition factor did not vary significantly with the increase in length and the fluctuations in these values have no particular trend. In case of *S. galilaeus,* the condition factor for all length groups ranged between 4.36 and 5.47 (Fig. 126). It is obvious that the condition factor values mostly decrease with the increase of body length.

Growth in length

Due to the fact that the life span of fish species is variable, fishes of Lake Nasser attain different age groups. Latif *et al.* (1979) calculated the standard length for the different age groups of some fish species from Lake Nasser (Fig. 127). It is obvious that *Lates niloticus* has the highest length value (i.e. 130 cm). On the other hand, *Brycinus nurse* has the lowest length value. The length attained by the oldest age group of a given species may be attained by another one at a younger age (Latif *et al.* 1979).

Aly (1993) calculated the standard lengths and increments for the different age groups of both *Mormyrus caschive* and *M. kannume* (Fig. 128). Adam (1994) calculated the standard lengths and increments for the different age groups of both *Oreochromis niloticus* and *Sarotherodon galilaeus* (Tables 82 and 83 and Fig. 129). The average actual standard lengths of *O. niloticus* for the successive age groups I to IV were 24.10, 29.95, 35.40, and 39.15 cm, while the calculated lengths were 17.26, 25.82, 32.15, and 37.72 cm respectively (Table 82). For *S. galilaeus* the average standard lengths for the successive age groups I to III were 22.35, 25.00 and 27.45

cm, however, the average calculated lengths were 16.16, 22.17 and 25.82 cm respectively (Table 83). These values are in accordance with those previously recorded in 1982 by Agaypi (1992a) who showed that *O. niloticus* attains 21.8 cm and 420 g, 26.3 cm and 500 g, 31.6 cm and 1100 g. and 39 cm and 2000 g at the first to fourth year of life, while *S. galilaeus* attains 20.6 cm and 400 g, 22.8 cm and 480 g and 25.2 cm and 700 g at age 1-3 years. The low values of lengths as given by back calculation may be attributed to the fact that they indicate the length of fish when the annual ring is formed.

The average calculated lengths of *O. niloticus* and *S. galilaeus* for different age groups, recorded by different authors are presented in Tables 84 and 85, respectively. It is obvious that, in all cases, the growth rate of *O. niloticus* is higher than that of *S. galilaeus.* Furthermore, Agaypi (1992a) in his studies on the growth of both *Tilapia* species collected during 1982 from six different fishing areas in the Lake, found that fish of both species caught from the southern region are larger in size (length and weight) than those collected from the northern areas.

Comparing the growth rates at different years of life of *O. niloticus* in Lake Nasser (Table 84) suggests that sizes recorded during 1989/1990 (Adam 1994) are much less than those recorded in 1970 (Abdel-Azim 1974) i.e. a decrease of the growth rate in recent years.

Table 82 **Actual and calculated lengths of *O. niloticus* for different age groups (Adam 1994).**

Age group	Actual standard length (cm)			Calculated length (cm)		No. of fish examined
	Range	Average	Increment	Average	Increment	
I	18-29	24.10	24.10	17.26	17.26	276
II	24-36	29.95	5.85	25.82	8.56	520
III	28-40	35.40	5.45	32.15	6.33	405
IV	34-45	39.15	3.75	37.72	5.57	73

Table 83 **Actual and calculated lengths of *S. galilaeus* for different age groups (Adam 1994).**

Age group	Actual standard length (cm)			Calculated length (cm)		No. of fish examined
	Range	Average	Increment	Average	Increment	
I	14-26	22.35	22.35	16.16	16.16	732
II	20-31	25.00	2.65	22.17	6.01	502
III	24-33	27.45	2.45	25.82	3.65	48

The growth rate of *O. niloticus* and *S. galilaeus* collected from different water bodies is presented in Tables 86 and 87 which show that the growth rate of *Tilapia* spp. in Lake Nasser is higher than that from other lakes, except for *O. niloticus* at Jebel Aulia (Sudan), where the growth rate is higher than that in Lake Nasser in the first and second years of life, and the values are nearly equal in the third year, while in the fourth year, the growth rate of fish in Lake Nasser is higher.

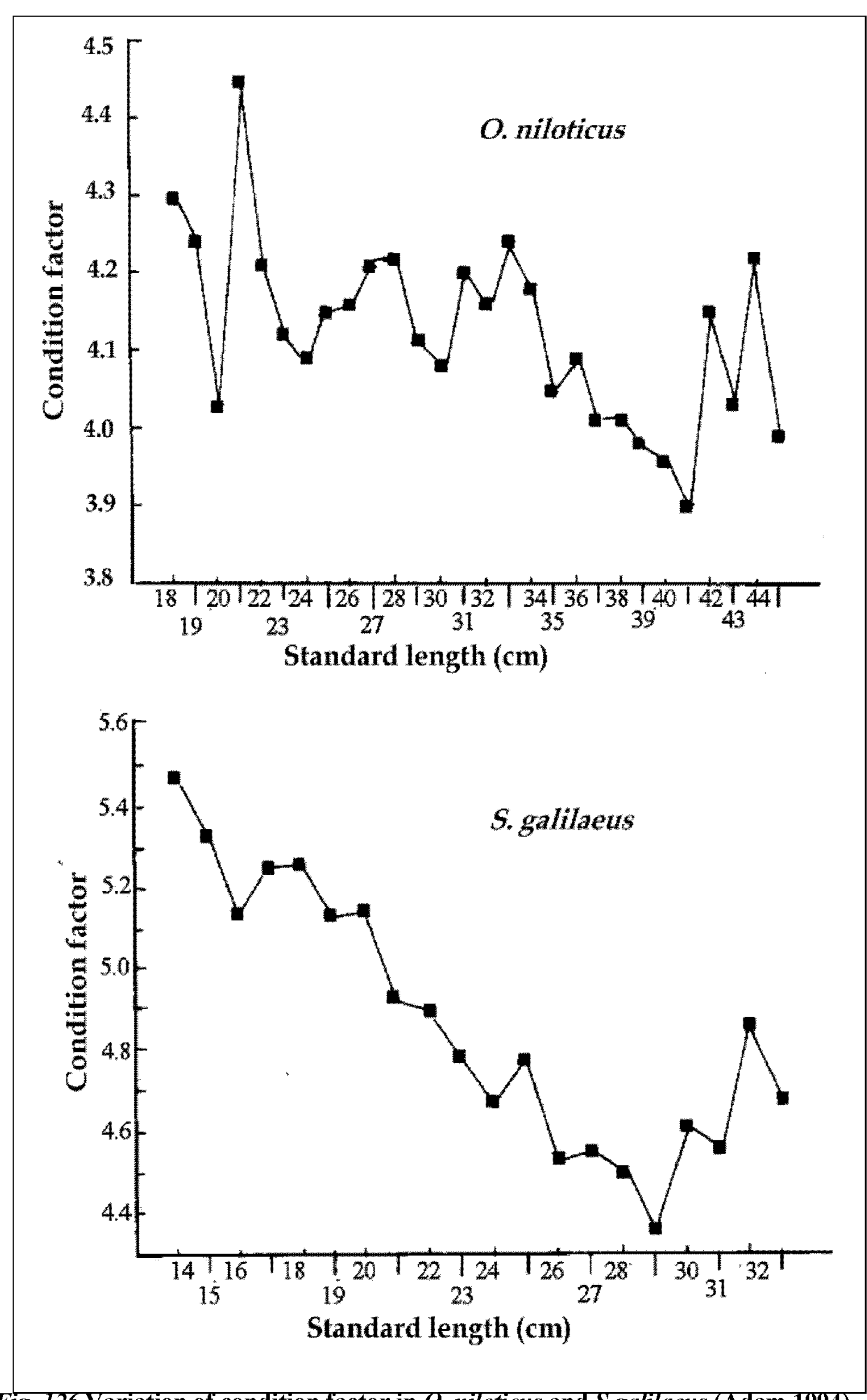


Fig. 126 **Variation of condition factor in *O. niloticus* and *S.galilaeus* (Adam 1994).**

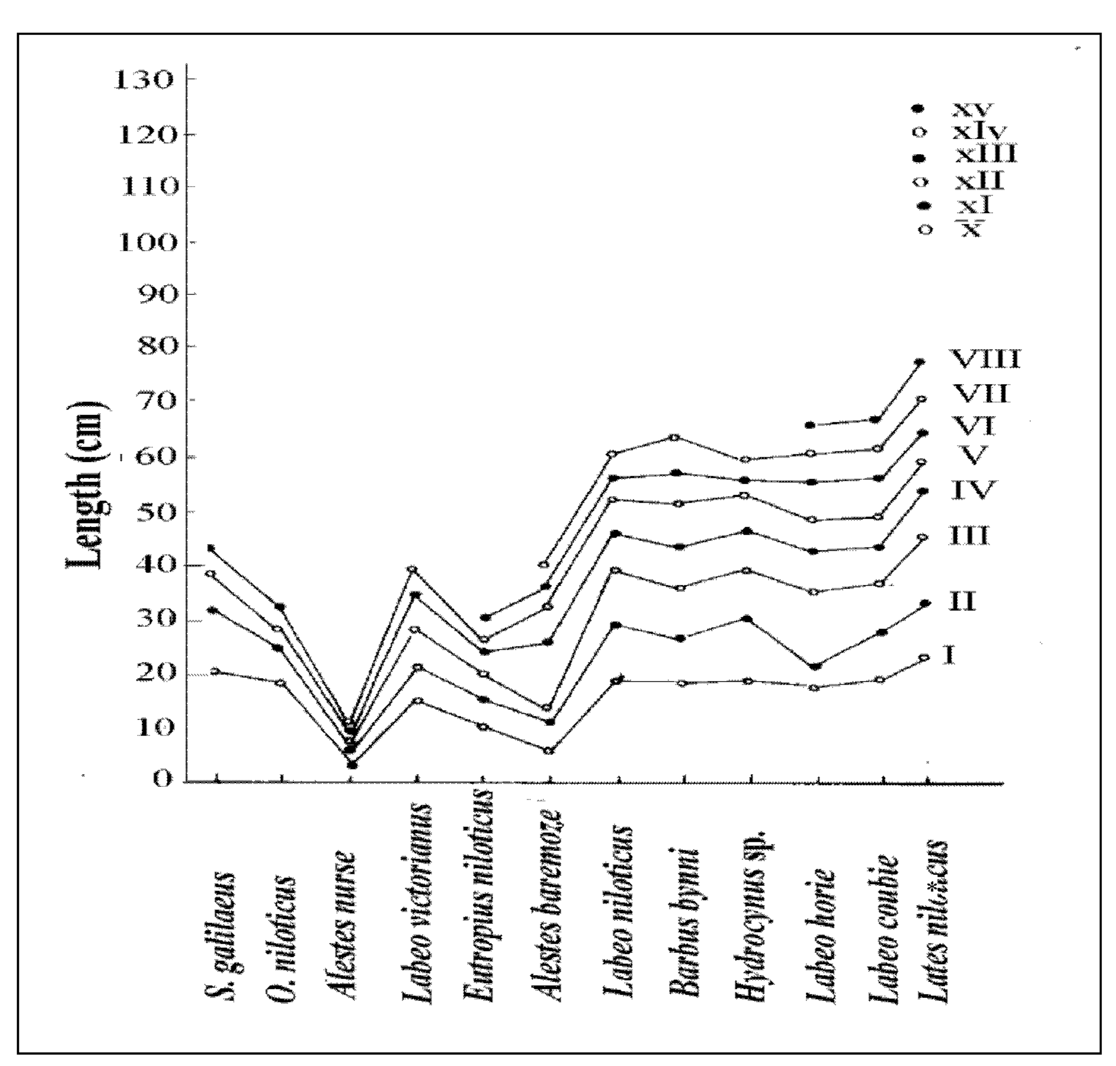


Fig. 127 **Calculated standard length for different age groups of some fish species (Latif *et al.* 1979).* *Lates niloticus* attains a length of 130 cm, at age group XV.**

Table 84 **Average calculated lengths of *O. niloticus* from Lake Nasser at different age groups (Different authors and periods).**

Author		Average calculated length (cm) for different age groups				Remarks
		I	II	III	IV	
Adam (1994) 1989-1990 (combined sexes)		17.26	25.82	32.15	37.72	SL
Yamagauchi *et al.* (1990)	♀	16.8	25.2	30.1	32.9	SL
	♂	17.3	25.4	30.9	34.7	SL
Agaypi (1992a) 1982		21.8	26.2	31.6	39.0	1-4 years (actual)
Abdel-Azim (1974) 1964/1970 (combined sexes)		20.0	29.6	35.5	40.2	SL

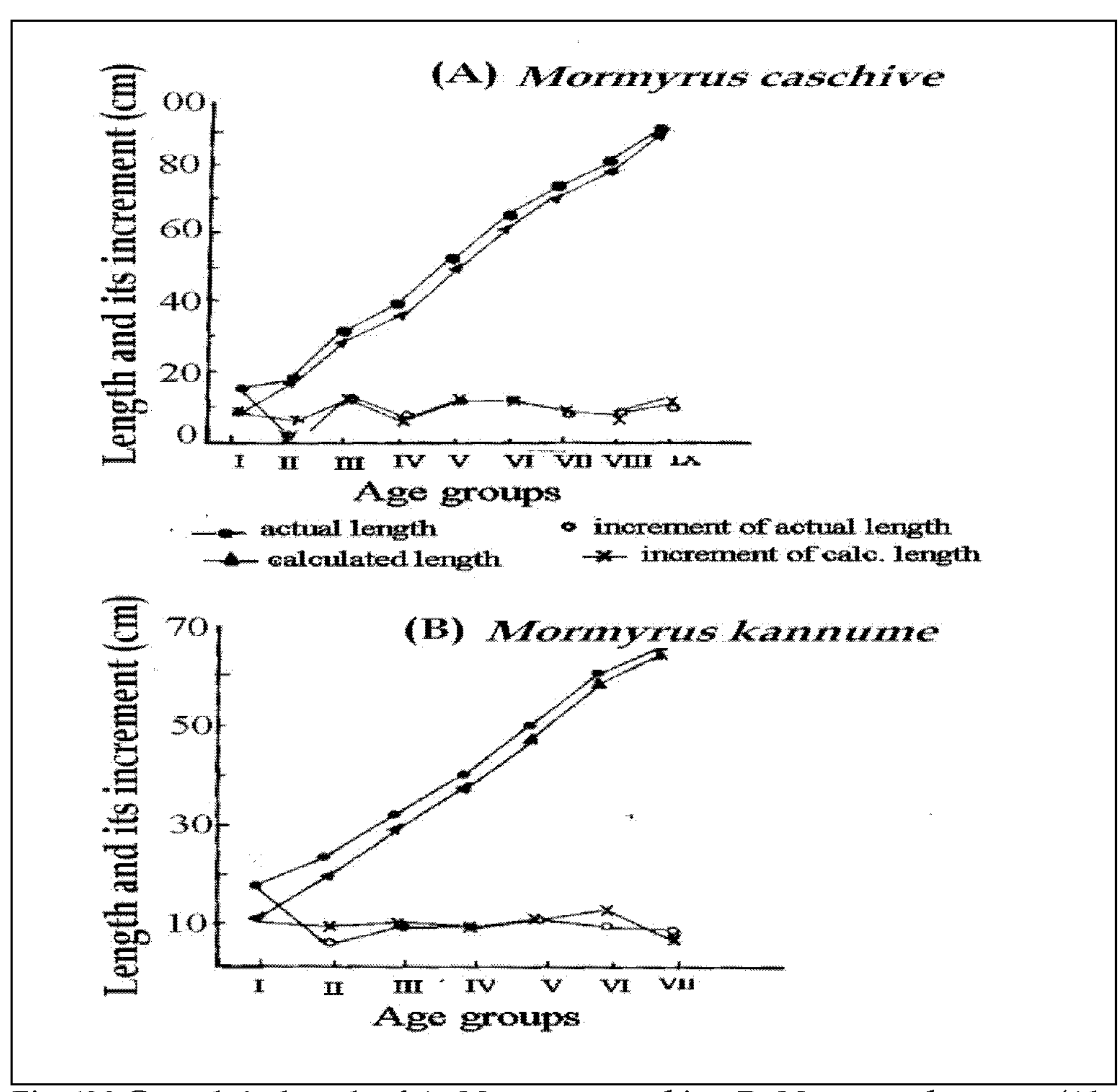


Fig. 128 **Growth in length of A:** ***Mormyrus caschive,*** **B:** ***Mormyrus kannume*** **(Aly 1993).**

Table 85 **Average calculated lengths of** ***S. galilaeus*** **from Lake Nasser at different age groups (Different authors and periods).**

Author		Average calculated length (cm) for different age groups				Remarks
		I	II	III	IV	
Adam (1994) 1989-1990 (combined sexes)		22.35	25.00	27.45	-	SL
Yamagauchi *et al.* (1990)	♀	13.4	19.7	23.4	25.6	SL
	♂	13.9	20.5	23.8	25.5	SL
Agaypi (1992b) 1982		15.4	17.2	19.1	-	1-3 years (actual)
Latif *et al.* (1979)		23.7	30.5	34.2	38.8	SL (years of life)
Abdel-Azim (1974) 1964/1970 (combined sexes)		18.63	24.76	28.06	32.20	SL

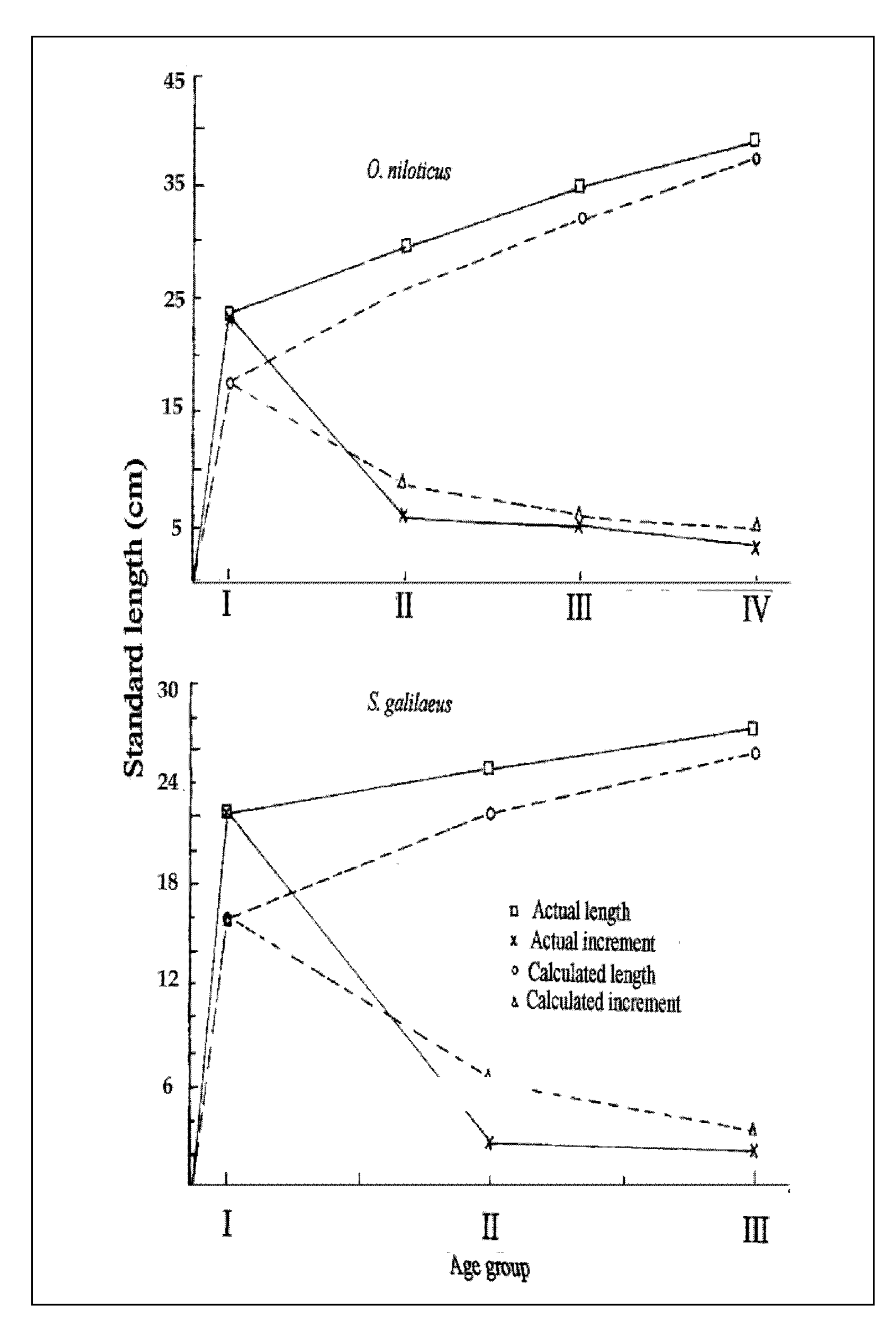


Fig. 129 **Growth in length of *O. niloticus* and *S. galilaeus* (Adam 1994).**

Growth in weight

The length-weight equations and the calculated lengths of the most important fish species in Lake Nasser, were used to obtain the calculated weights of different age groups. The calculated weights for different age groups of 14 fish species are presented in Table 88 (Latif *et al.* 1979 and Aly 1993, Fig. 130). From their results, it is obvious that the difference between different fish species, even those belonging to the same genus is more prominent with weight than with length. The results indicate that *Oreochromis niloticus* of age group IV has a calculated weight of 2836 g as compared with 1344 g for *Sarotherodon galilaeus* (i.e. more than twice).

Table 86 **Growth rate of *O. niloticus* in different localities.**

Lake and author	Calculated length (cm) of *O. niloticus* at the end of each year				
	1	2	3	4	5
Lake Nasser (Adam 1994)	17.26	25.82	32.15	37.72	--
Lake Nasser (Latif *et al.* 1979)	26.0	37.8	45.5	50.8	-
Lake Maryut (Jensen 1958)	9.20	20.50	25.70	28.80	-
Lake Maryut (El Zarka *et al.* 1970)	8.40	21.20	29.20	32.70	37.60
Beteha Area, Syria (El Bolock & Koura 1961)	9.90	16.40	20.40	27.50	--
Jebel Aulia, Sudan (Mahdi 1972)	24.40	28.80	32.00	36.00	43.70
Lake Tchad (Fryer & Iles 1972)	13.4	22.9	28.0	31.8	35.2*

*Actual total length at age (years)

Table 87 **Calculated total lengths (cm) of *Sarotherodon galilaeus* in different localities.**

Lake and author	Years of Life					
	1	2	3	4	5	6
Lake Nasser (Adam 1994) (1989-1990)	22.35	25.0	27.45	--	--	Standard length
Lake Nasser (Latif *et al.* 1979)	23.7	30.5	34.2	38.8	--	--
Lake Maryut (Jensen 1958)	8.3	21.6	25.3	27.7	28.1	29.8
Lake Tiberias (Ben Tuvia 1960)	13.8	22.7	37.4	31.5	32.5	34.1
Lake Tchad (Blache *et al.* 1964)	13.2	22.3	27.0	30.2	31.4	--

On the basis of the aforementioned length-weight relationships, Latif *et al.* (1979) calculated the weight of fishes for some selected lengths (Table 89 and Fig.131).

From the previous results it is obvious that some fish species are slender (as *Eutropius niloticus, Hydrocynus forskalii, Alestes baremoze*), others have heavier bodies (as *Labeo niloticus, L. forskalii, Lates niloticus* and *Barbus bynni*) and still others as *Sarotherodon galilaeus* and *Oreochromis niloticus* have the heaviest weight (Latif *et al.* 1979).

The calculated weights and the annual increments of growth in weight of *Bagrus docmak* and *B. bajad* for different age groups were recorded by El-Badawy (1991) (Tables 90 and 91). There is a significant difference in growth between *Bagrus bajad* and its relative *Bagrus docmak* which grows faster and lives for a longer age (Tables 90 and 91).

Adam (1994) calculated the weights and the annual increments of growth in weights of *Oreochromis niloticus* and *Sarotherodon galilaeus* for different age groups (Tables 92 and 93 and Fig. 132). In case of *O. niloticus,* the growth increment in weight for age-group I was the lowest (in contrast to length). The growth increment increased progressively in the older ages up to age group IV. It is obvious that the average weights of *O. niloticus* were higher than those of *S. galilaeus* (Tables 92 and 93). For *S. galilaeus,* the calculated weight of age group I was nearly equal to that of *O. niloticus;* while those of age groups II and III were lesser than the calculated values for the same age groups of *O. niloticus.* The growth increment in weight of *S. galilaeus* was the lowest for age group I, then increased at age-group II and decreased at age group III. When comparing the calculated lengths of *O. niloticus* and *S. galilaeus* given by Latif *et al.* (1979) and those found by Adam (1994) (Tables 86 and 87) it can be seen that calculated lengths of both species at various age groups during 1994 were lesser than those at 1974 suggesting a decrease in growth during the last two decades.

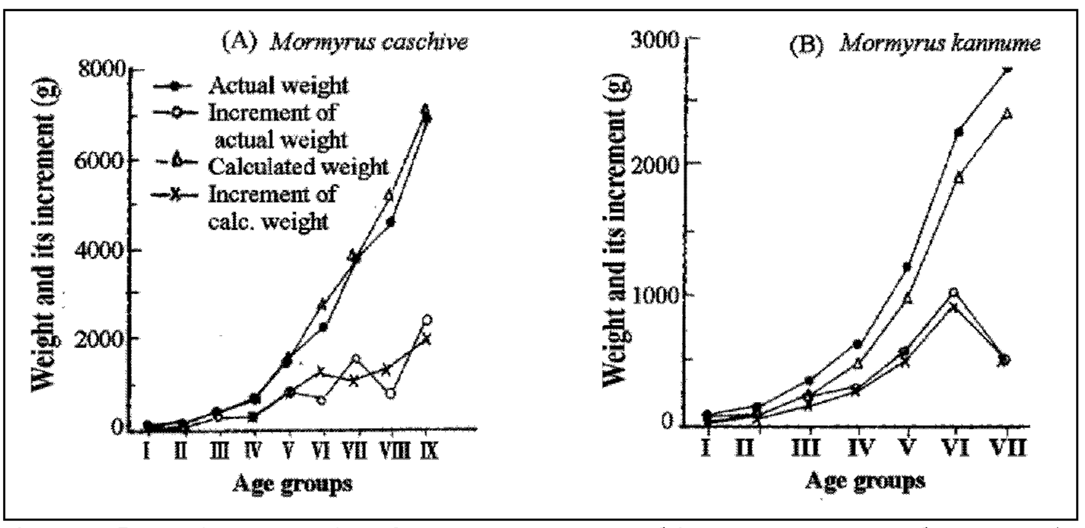


***Fig. 130* Growth in weight of A: *Mormyrus caschive,* B: *Mormyrus kannume* (Aly 1993).**

***Table 88* Calculated weights (g) of various fish species from Lake Nasser at different age groups (Latif *et al.* (1979).**

Fish species	Age Group									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Oreochromis niloticus	412.4	1301.0	2209.0	2836.00						
Sarotherodon galilaeus	315.5	674.9	943.5	1344.0						
Brycinus nurse	1.21	4.79	10.81	19.52	34.52					
Labeo forskalii	95.5	274.5	624.2	924.2	1332.0					
Eutropius niloticus	13.0	60.5	105.0	185.0	221.0	360.0				
Alestes baremoze	3.37	27.27	100.8	265.18	497.49	705.97	977.0			
Labeo niloticus	139.9	540.3	134.2	2260.5	3335.0	4395.0	5404			
Barbus bynni	156.1	521.9	1168	2107.7	3569.3	4922.5	6736			
Hydrocynus forskalii	815	331.1	731.6	1262	1861	2215	2556			
Labeo horie	172.2	708.2	1638	2615	3864	5429	6826	8271		
Labeo coubie	210.5	584.3	1180.9	2238.2	3181.3	4801	6232	7232		
Lates niloticus**	300	850	2350	3611	4598	6098	6250	1150	- - - -	20400*
Mormyrus caschive *	59.65	73.5	376.8	647.6	1446.75	2669.1	3779.8	5109.0	7061.9	- - - -
Mormyrus kannume *	11	68	219	477	990.5	1905.6	2422	- - - -	- - - -	- - - -

*Aly (1993), ***L. niloticus* attains 15 years old and 50.75 kg body weight.

Table 89 **Calculated weights (g) at different lengths of various fish species from Lake Nasser (Latif *et al.* 1979).**

Fish species	Standard length (cm)			
	10	15	20	30
	Calculated weight (g)			
Hydrocynus forskalii	11.2	38.9	93.9	325.2
Eutropius niloticus	10.9	39.3	97.5	351.3
Alestes baremoze	13.4	59.9	112.4	390.5
Labeo niloticus	23.2	66.1	163.5	585.7
Labeo forskalii	26.0	83.8	192.1	617.9
Lates niloticus	26.7	86.9	200.4	651.5
Barbus bynni	22.8	79.4	192.6	671.7
Labeo horie	31.9	102.1	232.9	744.2
Labeo coubie	31.1	101.0	233.1	757.5
Sarotherodon galilaeus	49.7	143.7	305.4	885.7
Oreochromis niloticus	62.8	168.5	354.3	1058.0

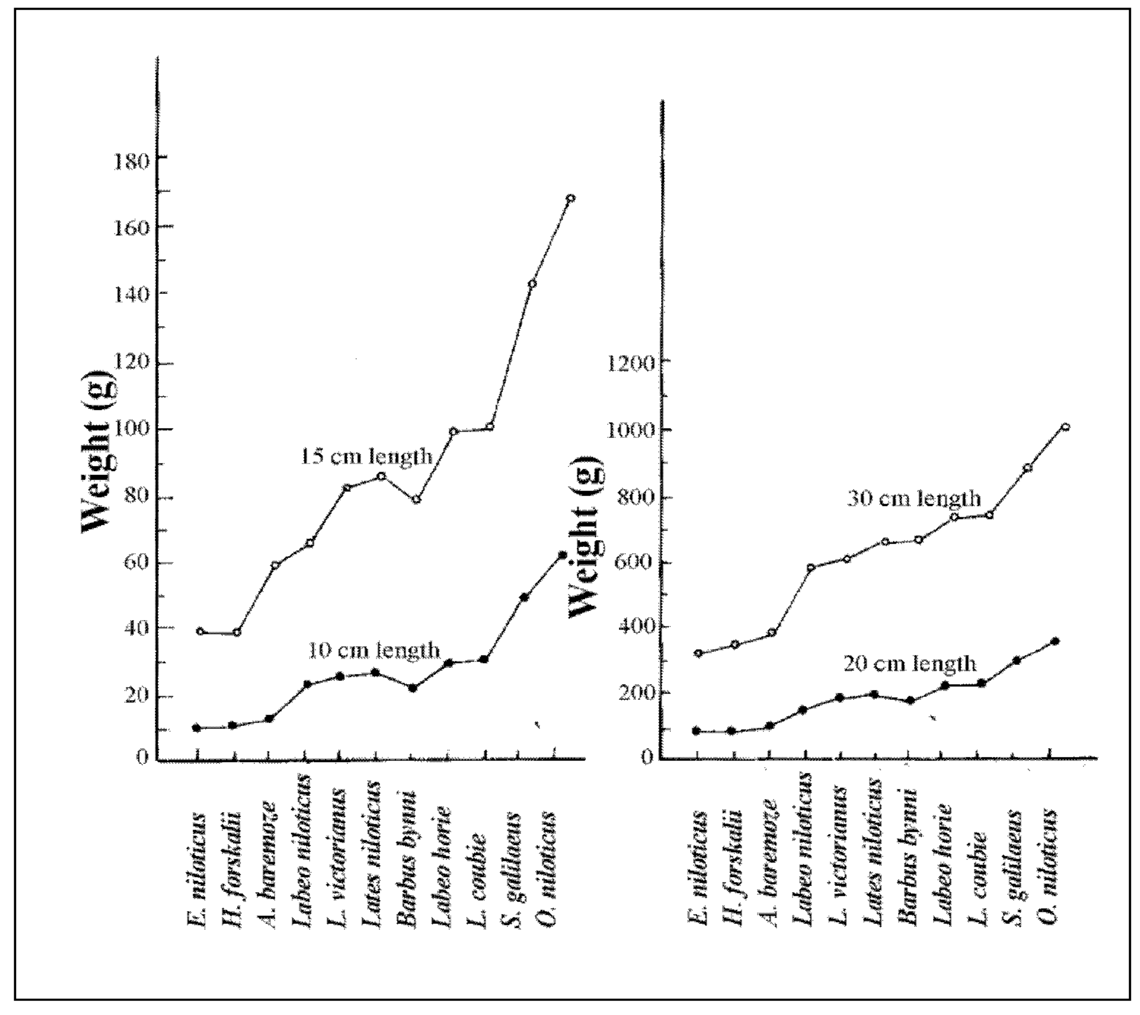


Fig. 131 **Calculated weights of some common species for some selected lengths (Latif *et al.* 1979).**

Table 90 **Actual and calculated weights and increments of *Bagrus docmak* for different age-groups (El-Badawy 1991).**

Age-group	Actual weight (g)		Calculated weight (g)		% weight from total
	Average	Increment	Average	Increment	
I	320	320	189	189	2.93
II	762	442	439	250	6.81
III	1388	626	1264	825	19.62
IV	2411	1023	1685	421	26.16
V	4346	1935	2688	1003	41.73
VI	11430	7084	6442	3754	100

Table 91 **Actual and calculated weights and increments of *Bagrus bajad* for different age-groups (El-Badawy 1991).**

Age-group	Actual weight (g)		Calculated weight (g)		% weight from total
	Average	Increment	Average	Increment	
I	428	428	253	253	11.5
II	833	405	588	335	26.84
III	1577	744	1013	425	46.23
IV	2166	589	1513	500	69.06
V	2789	623	2191	678	100

Table 92 **Actual and calculated weights and increments of *O. niloticus* for different age-groups (Adam 1994).**

Age-group	Actual weight (g)		Calculated weight (g)		% weight from total
	Average	Increment	Average	Increment	
I	598.10	598.10	219.58	219.58	10.04
II	1153.15	555.05	717.82	498.24	32.82
III	1866.45	713.30	1367.30	649.48	62.52
IV	2553.56	687.11	2187.12	819.82	100

Table 93 **Actual and calculated weights and increments of *S. galilaeus* for different age-groups (Adam 1994).**

Age-group	Actual weight (g)		Calculated weight (g)		% weight from total
	Average	Increment	Average	Increment	
I	539.92	539.92	221.15	221.15	27.17
II	746.17	206.25	532.78	311.63	65.47
III	970.63	224.46	813.82	281.04	100

Effect of impoundment on the growth of *Tilapia* spp. in Lake Nasser

Comparing the lengths and weights of *O. niloticus* and *S. galilaeus* recorded by Abdel-Azim (1974) during the early filling of Lake Nasser (1964/70) and those of Adam (1994) (Tables 82, 83, 92 and 93 and Fig. 132),

Mekkawy *et al*. (1994) and Mekkawy & Mohamed (1995) during 1989/1990 and the calculated lengths of both species given by Latif *et al*. (1979) (Figs. 133 and 134) a remarkable decrease in size is observed for both tilapiine species during the last two decades.

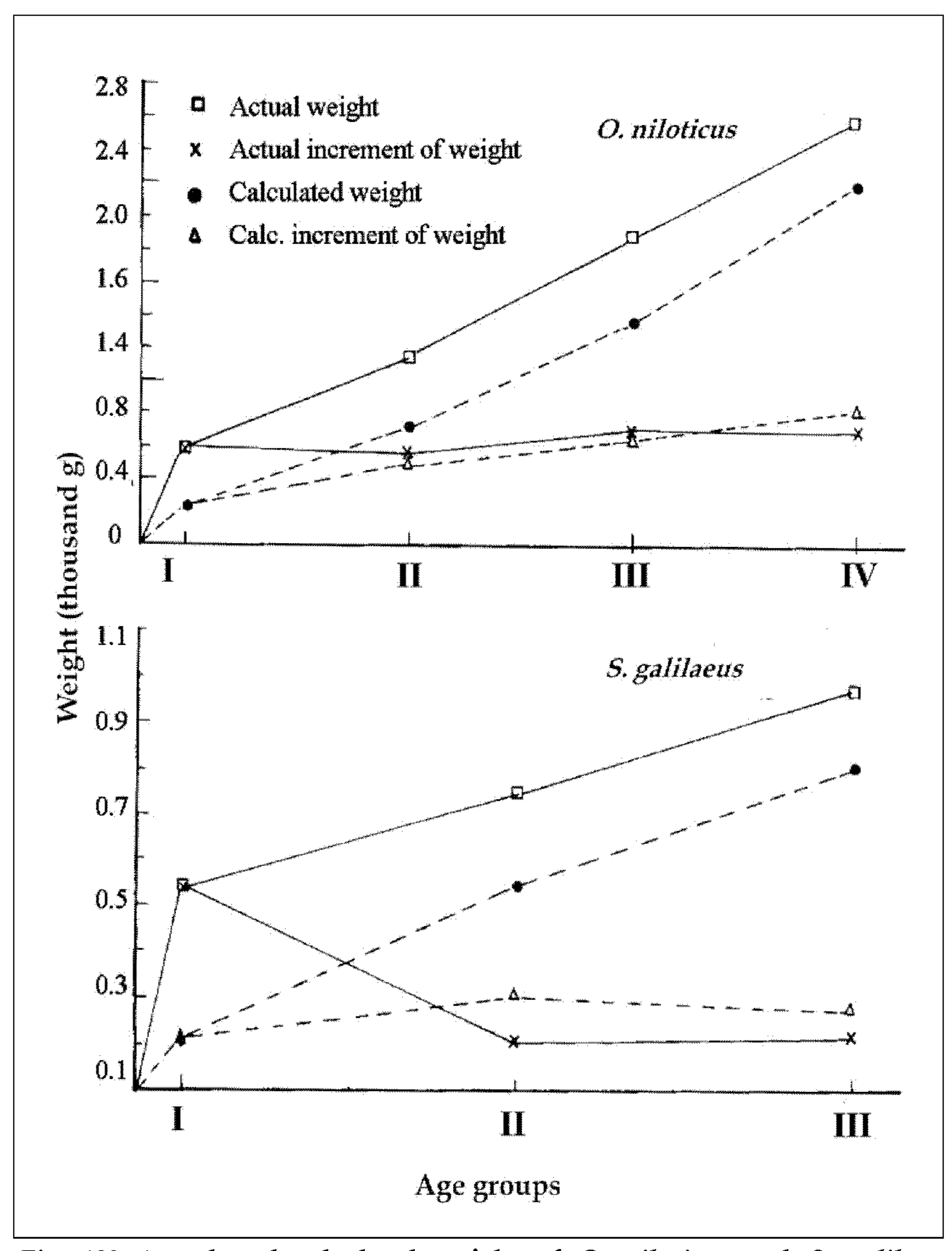


Fig. ***132*** **Actual and calculated weight of *O. niloticus* and *S. galilaeus* (Adam 1994).**

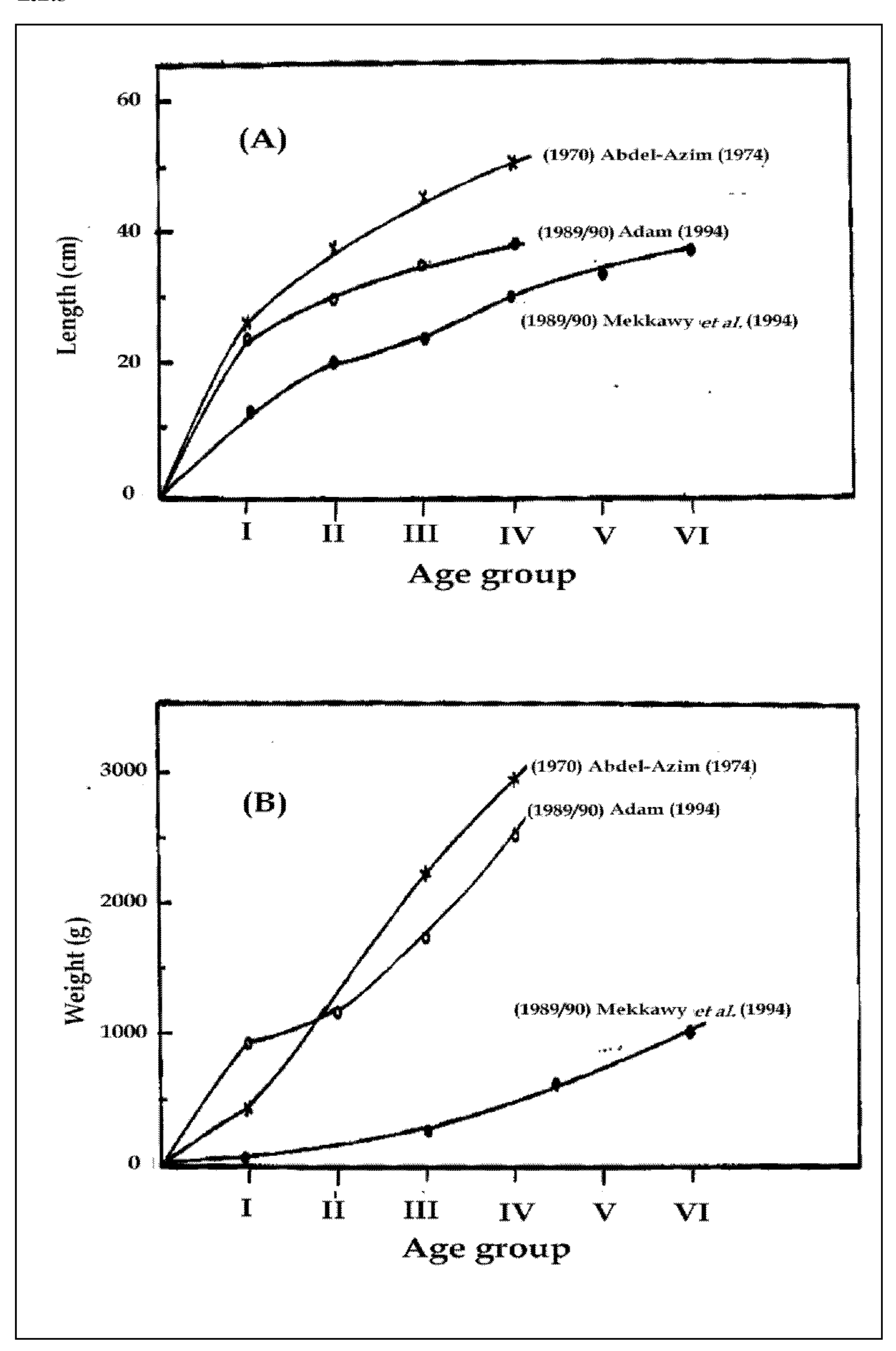
When considering the results obtained by Adam (1994) and those of Mekkawy *et al.* (1994), and Mekkawy & Mohamed (1995), on the growth of both tilapiine species in Lake Nasser, during the same period (1989-1990), remarkable differences between their results are noticed. Thus, while Adam (1994) mentioned that the actual weights of *O. niloticus* at age groups I-IV ranged between 598.1 and 2553.6 g (Table, 92), Mekkawy *et al.* (1994) pointed out that the range was 150-875 g (Fig. 133B) for the same age groups. Moreover, Adam (1994) showed that the weights of *S. galilaeus* ranged between 539.9 and 970.6 g (Table, 93) for age group I-III. Mekkawy & Mohamed (1995) indicated that this range was 80-220 g (Fig. 134B) for the same age groups. It seems that figures given by Mekkawy *et al.* (1994) and Mekkawy & Mohamed (1995) are too low and do not represent the actual sizes of both tilapiine species fished during recent years. This view is supported by the results of recent studies carried out on the fisheries of Lake Nasser (SECSF, 1996) at four sectors covering the Lake (Khors: 1-El Ramla, Dihmit, Kalabsha, 2-Absco, Garf Hussein, Allaqi, 3-Wadi El Arab, Korosko, Thomas, Afiah, 4-Enaba, Tushka, Hemadeh) which showed the following:-

1. The percentage of *O. niloticus* of 500 g and less (less than 25 cm long) was about 6.3% of the total production by weight and more than 25% of the total number fished. The highest percentage (9.5%) was that for fish collected from sector 1, while that from the other sectors ranged from 2.5-3.8% where fish more than 500 g and 30 cm long were dominant. Furthermore, the average weight of *O. niloticus* collected from all sectors more than 500 g ranged from 532.9 to 4253.3 g and 23-47.9 cm long. Referring to the sizes recorded by Mekkawy *et al* (1994- Fig. 133) it is obvious that the maximum length and weight of *O. niloticus* was 34 cm and 875 g, being much less than that recorded by Adam (1994) and SECSF (1996).

2. The percentage weight of *S. galilaeus* less than 500 g and less than 23 cm long was 87% of the total production representing 92.1% of the total fish production by weight from sector 1 (El Ramla, Dihmit and Kalabsha). Furthermore, fishes ranging from 13 to 22.9 cm long ranged from 142.5 to 483.9 g; while those from 23 to 31 cm ranged from 557.1 to 1150 g. Thus, it seems that the dominant size of *S. galilaeus* was less than 23 cm long and less than 500g. When referring to Fig. 134, it is obvious that figures recorded by Mekkawy *et al* (1994) showing a maximum length of 23.5 cm and weight of 310 g for age group V, are much lower than those given by Adam (1995a & b) working during the same period and less than those recorded in 1996 (SECSF).

Nevertheless, it seems that during the last two decades a decrease in size of both tilapiine species occurred, being more remarkable in fishes from the northern region than from the southern one. This may be attributed - among other factors - to the effect of impoundment of Lake Nasser. Similar observations on the effect of impoundment on the diversity and biological characteristics of cichlids were reported for Lake Kainji (Lelek 1973, Balogun 1986), Lake Kariba (Balon & Coche 1974), Lake Kamburu (Dadzie 1980),

Lake



(A)
Length (cm)
60
40
20
0
(1970) Abdel-Azim (1974)
(1989/90) Adam (1994)
(1989/90) Mekkawy et al. (1994)
I
II
III
IV
V
VI
Age group
(B)
Weight (g)
3000
2000
1000
0
(1970) Abdel-Azim (1974)
(1989/90) Adam (1994)
(1989/90) Mekkawy et al. (1994)
I
II
III
IV
V
VI
Age group

Fig. 133 **Growth in length (cm) A; and weight (g), B; of different age groups of *O. niloticus* during different periods.**

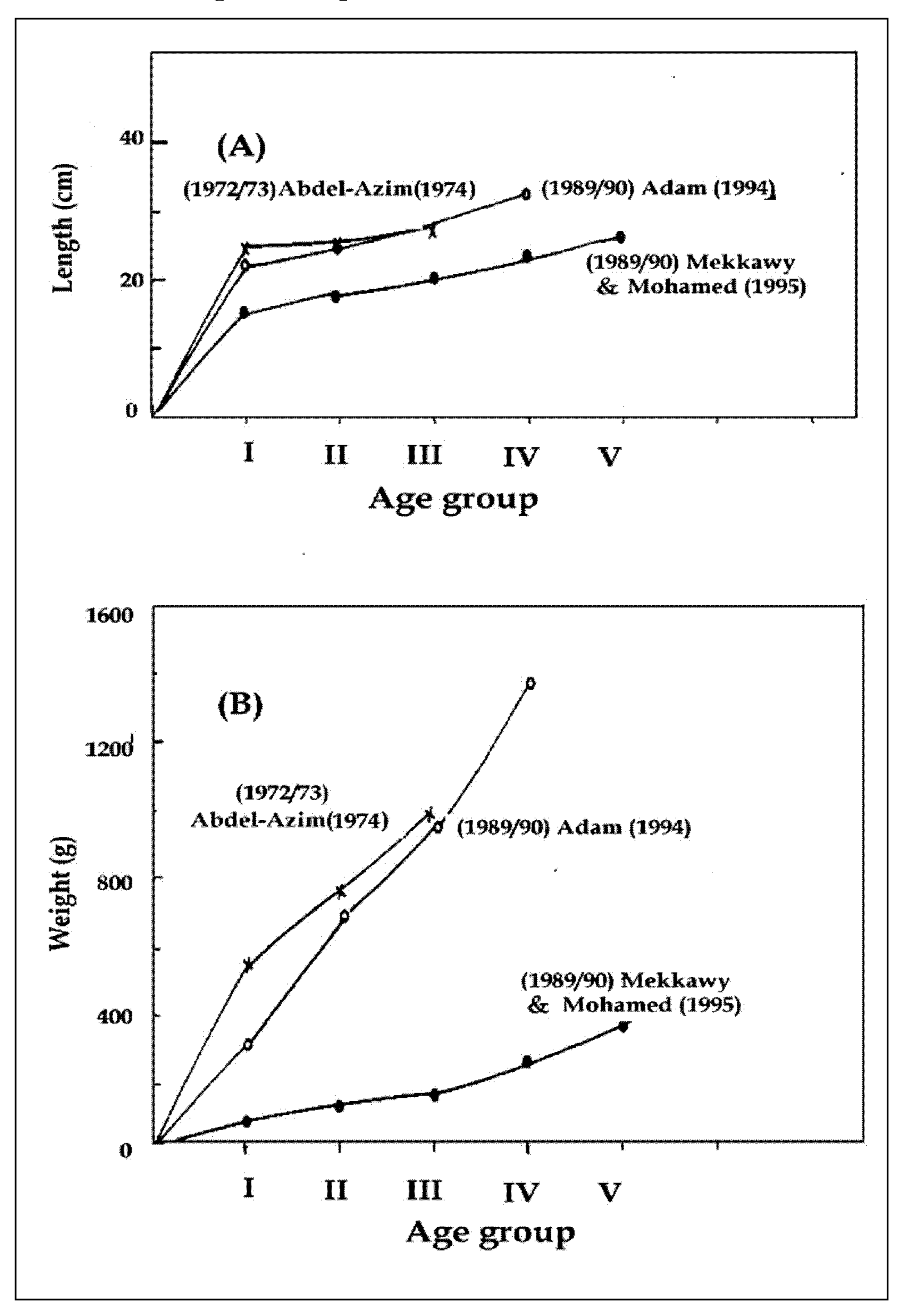


Fig. 134 **Growth in length (cm) A: and weight (g), B: of different age groups of *S. galilaeus* during different periods.**

Itezkitezhi (Kapasa & Cowx 1991) and Lake Nubia (Ali 1984). Mekkawy & Mohamed (1995) concluded that cichlids, especially *O. niloticus* and *S. galilaeus,* had a great ability, as reflected by their past impoundment prominence in the normal and dry conditions in the aged lakes, to adapt to the new lacustrine habitat, to feed on different items and to spawn successfully in a balanced equilibrium with the ecological and biological conditions. Furthermore, among tilapiine fishes *S. galilaeus* were able to adapt to special environmental factors and to predominate (Ben-Tuvia *et al.* 1992) in Lake Kinnert (Lake Tiberias) at the time at which *O. niloticus* declined (Ben-Tuvia 1960) and disappeared completely from the Lake (Ben-Tuvia *et al.* 1992). In Lake Nasser and other Egyptian lakes, *O. niloticus* has a higher growth rate than *S. galilaeus.* Further investigations on the other fish species of Lake Nasser are needed to find out the effect of impoundment and whether a decrease in their growth rate occurred in recent years on the basis of previous studies on the growth of these species.

3. REPRODUCTIVE BIOLOGY

The knowledge of reproductive biology : spawning season, length at first maturity, fecundity, etc. is one of the most important aspects in the development of fisheries by suggesting the suitable time for protection of fisheries, suitable size to be fished and also to prevent over-exploitation.

Spawning season

Based on the analysis of gonad index (Table 94), egg diameter and frequency of maturity stages, fishes of Lake Nasser may be assorted into three main groups:

a. The first group of fishes have a relatively long spawning season (e.g. *Lates niloticus, Brycinus nurse, Oreochromis niloticus, Sarotherodon galilaeus*). Two peaks at least were recorded, the first peak during March-May and the second during August-September (Figs. 135 and 136).

b. The second group particularly females are mature only in July, August and September (e.g. *Eutropius niloticus, Alestes baremoze, Mormyrus kannume, M. caschive, Labeo coubie, L. horie, Barbus bynni* (Figs. 137 - 139), *Synodontis schall, Schilbe uranoscopus, Petrocephalus bane, and Mormyrops anguilloides*). Spawning probably coincides with the commencement of the flood, which may stimulate this process. In other words, they are summer spawners.

c. Winter spawners mainly *Labeo niloticus*.

Spawning behaviour

O. niloticus and *S. galilaeus* are nest builders that prepare the nests in fine sand, sometimes with fine gravel in shallow waters particularly in khors or inundated areas. *Bagrus* spp. build also nests on the bottom substrate, close to some rocky areas. *Lates niloticus* is extremely different as it lays pelagic eggs. Large individuals of *Clarias gariepinus* were seen very actively swimming and

thrashing about amid partially submerged weeds, during the spawning season, an act which is probably connected with spawning.

It seems that most fishes of Lake Nasser have limited movements for their spawning runs especially *Tilapia* spp. which move to the shallow coastal waters with sandy bottom where they build their nests. However, *Alestes baremoze* behave differently as males and females move upstream beyond the Second Cataract and Amada area. There, they dwell along the narrow part of the reservoir where they become affected by the early washes of the flood which probably induces the process of spawning. This spawning behaviour of *Alestes baremoze* is similar to that occurring in other African waters. Thus, Daget (1952) recorded mass spawning of this species in the middle of Niger coinciding with heavy rain which causes sudden drop of temperature. Hopson (1972) postulated that mass movement of *A. baremoze* from Lake Tchad to the river takes place each year at the flood time and that this migration is primarily connected with spawning.

Macroscopic peculiarities of the gonads

Maturity stages. The monthly frequency (%) of different maturity stages of *O. niloticus* is graphically presented in Fig. 140 (Adam, 1994). It is obvious that for females *O. niloticus,* the mature stages (IV and V) increased gradually from 29% in January to reach the maximum value (86%) in April. Then, a decline was noticed in July (24%), followed by a slight increase in August and September (27% and 28% respectively). A sharp decrease was observed in October and November to reach 8% only, followed by a slight increase (11%) in December (Fig. 140). The frequency of mature testes of *O. niloticus* increased gradually from 24% in January to 78% in April, followed by a progressive decrease to reach 25% in June. A gradual increase was noticed during the period from July till September (29%; 31% and 46% respectively). A sharp decrease was recorded in October (15%), followed by an increase of 21% in November to 28% in December (Fig. 140). These results suggest that *O. niloticus* is a multispawner spawning about 2-3 times during the year with a maximum in March-May.

Gonad index (GI). On analyzing the gonad index of Lake Nasser fishes, Latif *et al.* (1979) assorted two main groups. The first one: *Brycinus nurse, O. niloticus, S. galilaeus* and *Lates niloticus* have prolonged spawning season with two peaks (March - May and August - September, Figs. 135 and 136). The second group of fishes: *A. baremoze; Eutropius niloticus, Labeo coubie, L. horie, Barbus bynni, Synodontis schall, Schilbe uranoscopus,* are mature only during the period July-September (Fig. 137).

The monthly variations of gonad index of *Mormyrus kannume* and *M. caschive* were studied by Aly (1993). Fig. 138 shows a gradual increase of the gonad index of females and males of *M. kannume* in June which attains its maximum (6.2 and 0.44 respectively) in July followed by a sharp decrease in the

value of gonad index till October. For *M. caschive,* almost the same trend was observed (Fig. 139)

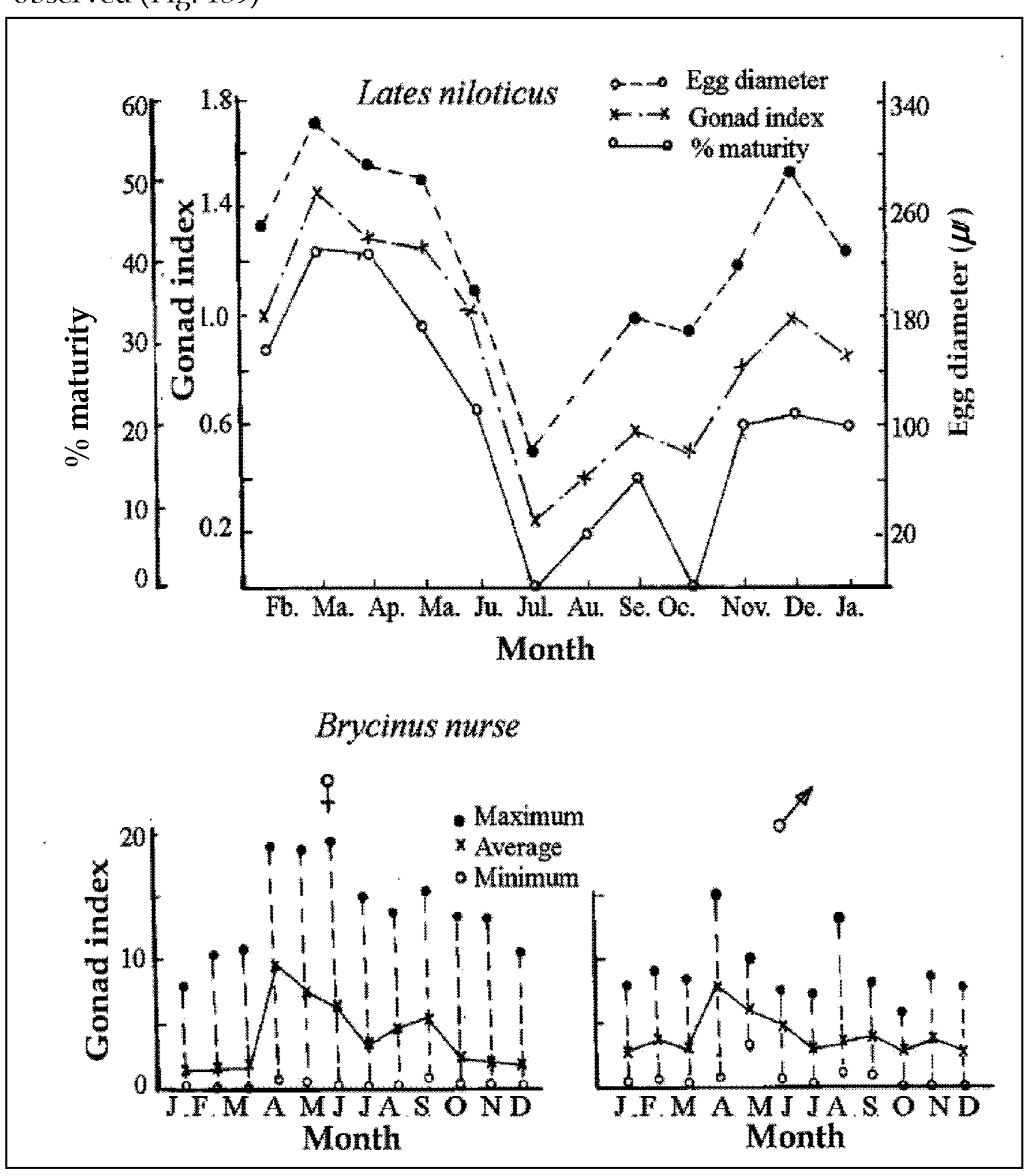


***Fig. 135* Gonad index of *Lates niloticus* and *Brycinus nurse* (Latif *et al.* 1979)**

Studies of Adam (1994) on the monthly variations of gonad index of *Oreochromis niloticus* (females and males) (Fig. 136) showed a gradual increase of the mean value of gonad index of female *O. niloticus* from January (0.540) to February (0.835) to March (1.266) then reached its maximum in April (1.408), followed by a decrease (0.909) in May. The mean gonad index of male *O. niloticus* was 0.117, 0.206 and 0.101 in March, April and May respectively (Fig. 136). However some females and males are mature during all months of the year. Adam (1994) concluded that the main spawning season of *O. niloticus* is during the period from March to May, and the second one in September. Latif

and Rashid (1972) found that whether in female or male *O. niloticus* the average gonad index has two modes, appearing in April and September in females, being a month earlier in males.

Adam (1996a) pointed out that the spawning season of *S. galilaeus* extends from March to September. The monthly maximum gonad index (GI) of females ranged from 2.415 to 6.317 indicating that some females are fully mature and spawn allover the year. The monthly maximum (GI) of males ranged from 0.080 to 0.310 during all months, an indication that some males are fully mature and spawn allover the year. It is concluded that one of the reasons that may account for the predominance of *S. galilaeus* in Lake Nasser over *O. niloticus* is that its spawning extends throughout the year, while spawning of *O. niloticus* occurs about 2-3 times during the year. This suggests a competition for the spawning grounds of both species which have the same spawning behaviour. Furthermore, in *S. galilaeus* both parents are mouth brooders while in *O. niloticus* only females are mouth brooders.

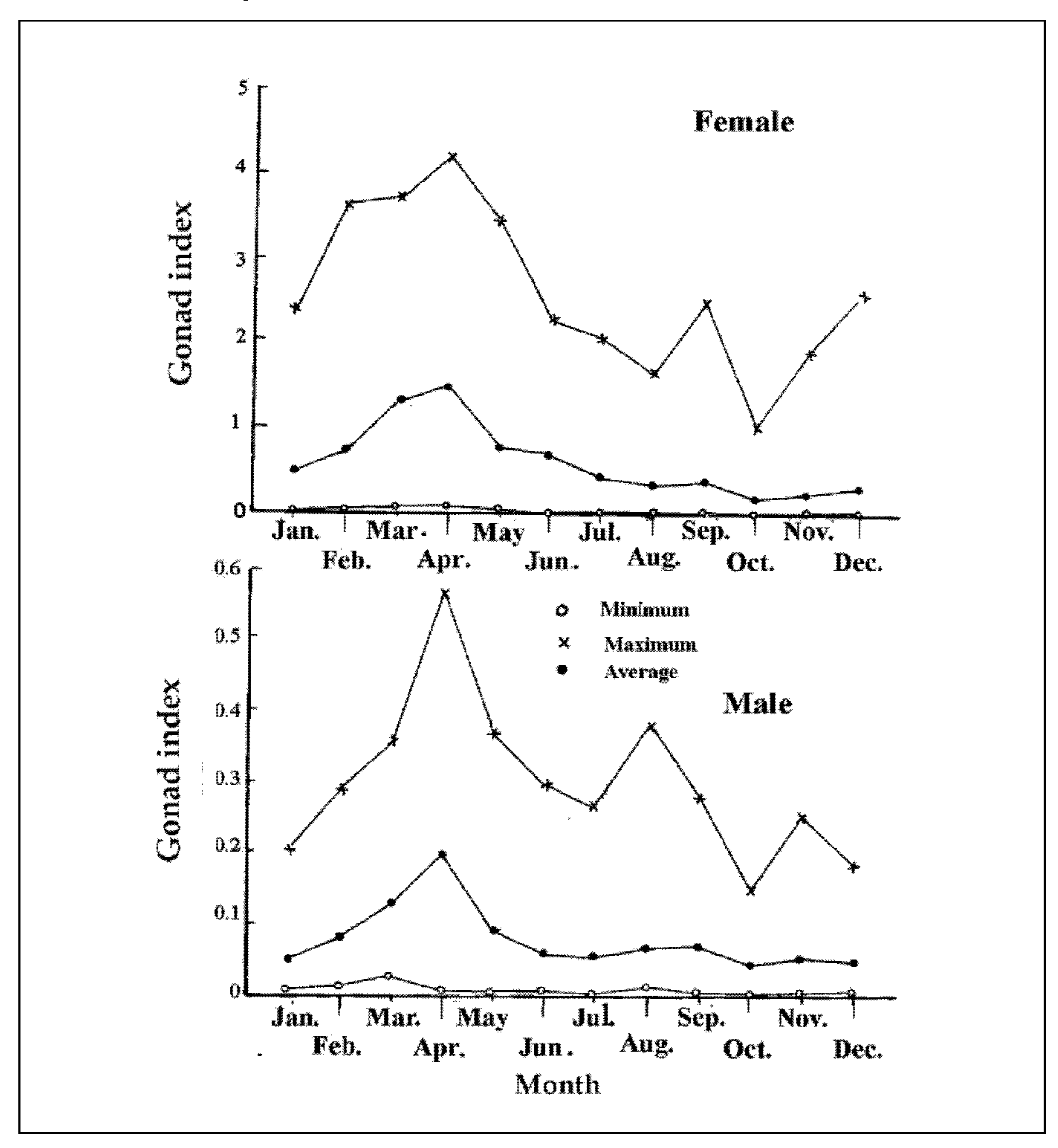


Fig. 136 **Monthly variation of gonad index of *O. niloticus* (Adam 1994).**

Table 94 **Gonad index of mature-ripe females of different species during spawning periods.**

Species	Period		Gonad Index Maximum	Gonad Index Minimum
		A. Cichlids		
Oreochromis niloticus	Jan.	- March	3.75	0.1
	April	- June	4.3	0.2
Sarotherodon galilaeus	Feb.	- March	5.83	2.12
	April	- May	4.21	1.58
	June	- August	3.53	0.97
	Dec.	- Nov.	3.73	1.06
		B. Centropomids		
Lates niloticus	Feb.	- June	5.14	1.01
	September		2.12	0.58
	Nov.	- Dec.	2.86	0.82
		C. Characins		
Brycinus nurse	Jan.	– March	11.30	1.59
	April	- June	19.95	1.8
	July	- Sept.	15.53	1.7
Alestes baremoze	July	- August	15.12	0.98
Hydrocynus forskalii	Jan.	- March	9.38	1.25
	April	-	12.51	4.54
	May	-	5.49	0.98
	July	- August	6.76	1.52
		D. Cyprinids		
Barbus bynni	March	- July Nov.	9.0	0.5
	Sept.	-	6.8	1.0
Labeo niloticus	Dec.	- Feb.	18.87	0.82
	April	- August	--	2.09
Labeo coubie	May	- Sept.	4.29	0.50
Labeo horie	April	- July	13.48	--
		E. Catfishes		
Bagrus bajad	August	- April	2.22	--
Bagrus docmak	August	- May	1.47	0.66
Synodontis schall	July	- August	15.75	1.36
Synodontis serratus	July	- May	5.87	0.53
Clarias gariepinus	October		4.27	--
Eutropius niloticus	July	- Sept.	11.7	--
Schilbe uranoscopus	July	- Sept.	7.71	3.63
		F. Mormyrids		
Mormyrus kannume	May	- August	6.3	3.8
	Jan	- April	3.5	1.2
Mormyrus caschive	May	- August	6.8	5.0
	Jan.	- April	4.0	0.7
Petrocephalus bane	July	- August	4.07	0.50
Mormyrops anguilloides	July	- August	0.90	0.50

Ref. Rashid (1995), Adam (1994), Aly (1993), Abdel Shahid *et al.* (1993), Latif *et al.* (1979).

Egg characteristics. The mature or ripe eggs of most fishes of commercial importance in Lake Nasser are large in size (600-2800 μ) and can be seen by the naked eye. The eggs are spherical in most fishes or pear-shaped in

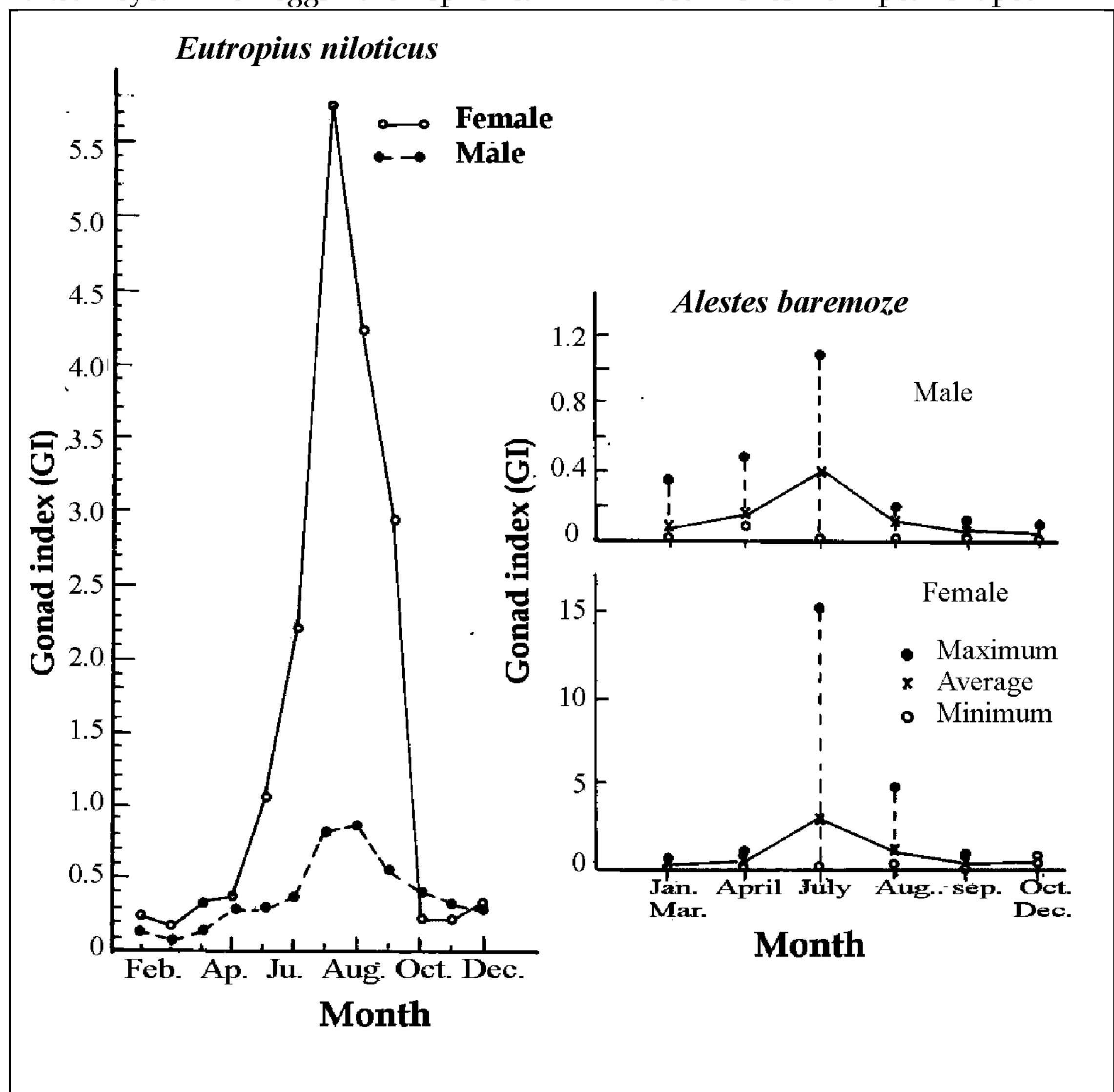


Fig. 137 Gonad index of *Eutropius niloticus* and *Alestes baremoze* (Latif *et al.* 1979).

Oreochromis niloticus . The colour of eggs is orange in *Barbus* species, cream in *Lates niloticus*, greenish-gray in *Labeo* spp. The eggs vary in size from one species to another. The smallest are the pelagic eggs of *Lates niloticus* (600-775μ), while the largest are those of *Oreochromis niloticus* (2800 μ) and *Sarotherodon galilaeus* (2500 - 2800 μ) (Table 95).

Adam (1994) studied the monthly variation in the size of the oldest ovarian eggs of *O. niloticus* (Fig. 141). The latter author found that the average egg diameter increased from 1675 μ in January to reach its maximum value (2150μ) in May, followed by a sharp decrease to 1708 μ in June and 1701 μ in July. Again, the average value increased from 1750 μ to 1842 μ in August and

September respectively, followed by a sharp decrease (1461µ) in October, 1450 µ in November and finally increased to 1525 µ in December. Thus the monthly

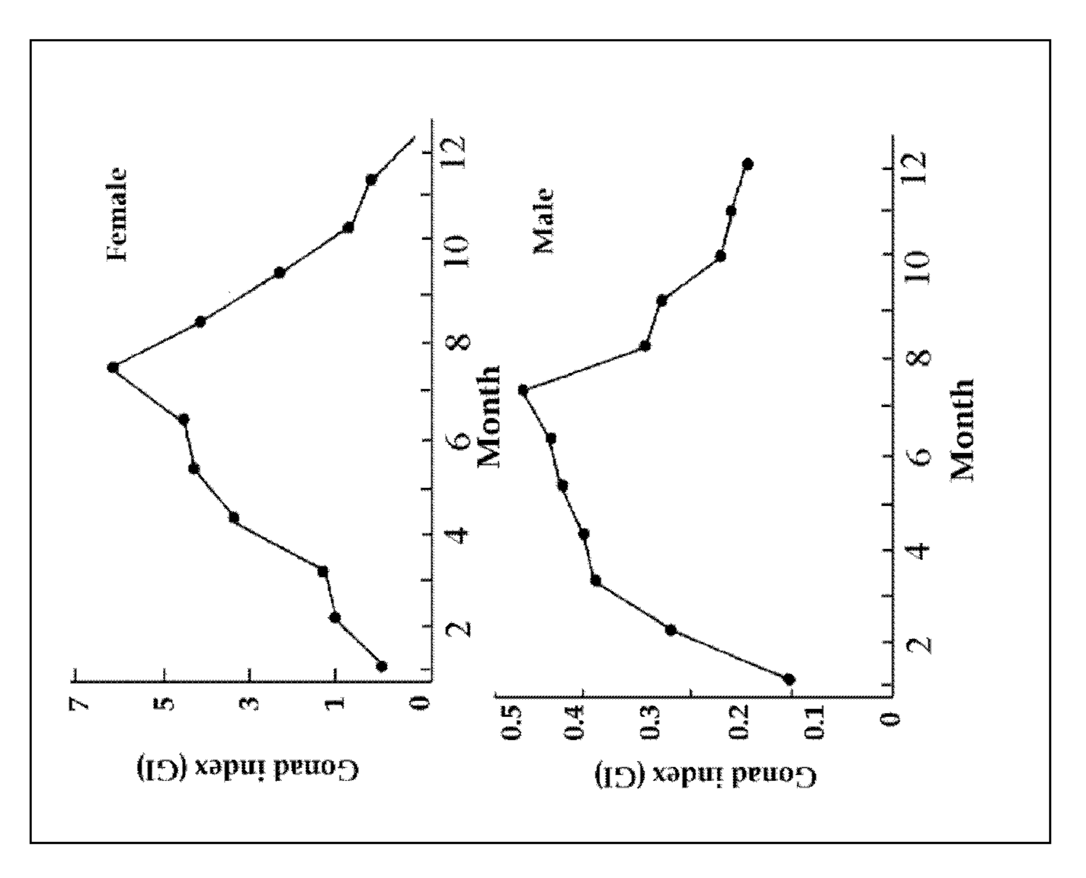


Fig 139 **Monthly gonad index of *M. caschive* (Aly 1993).**

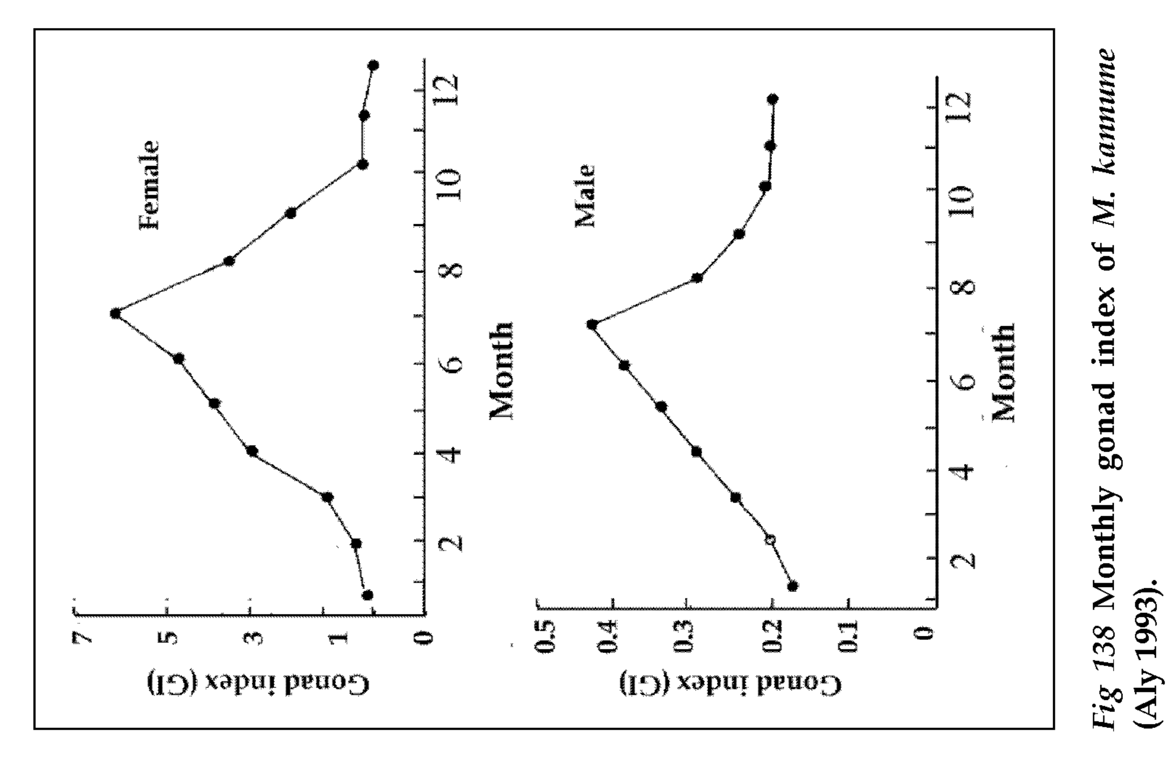
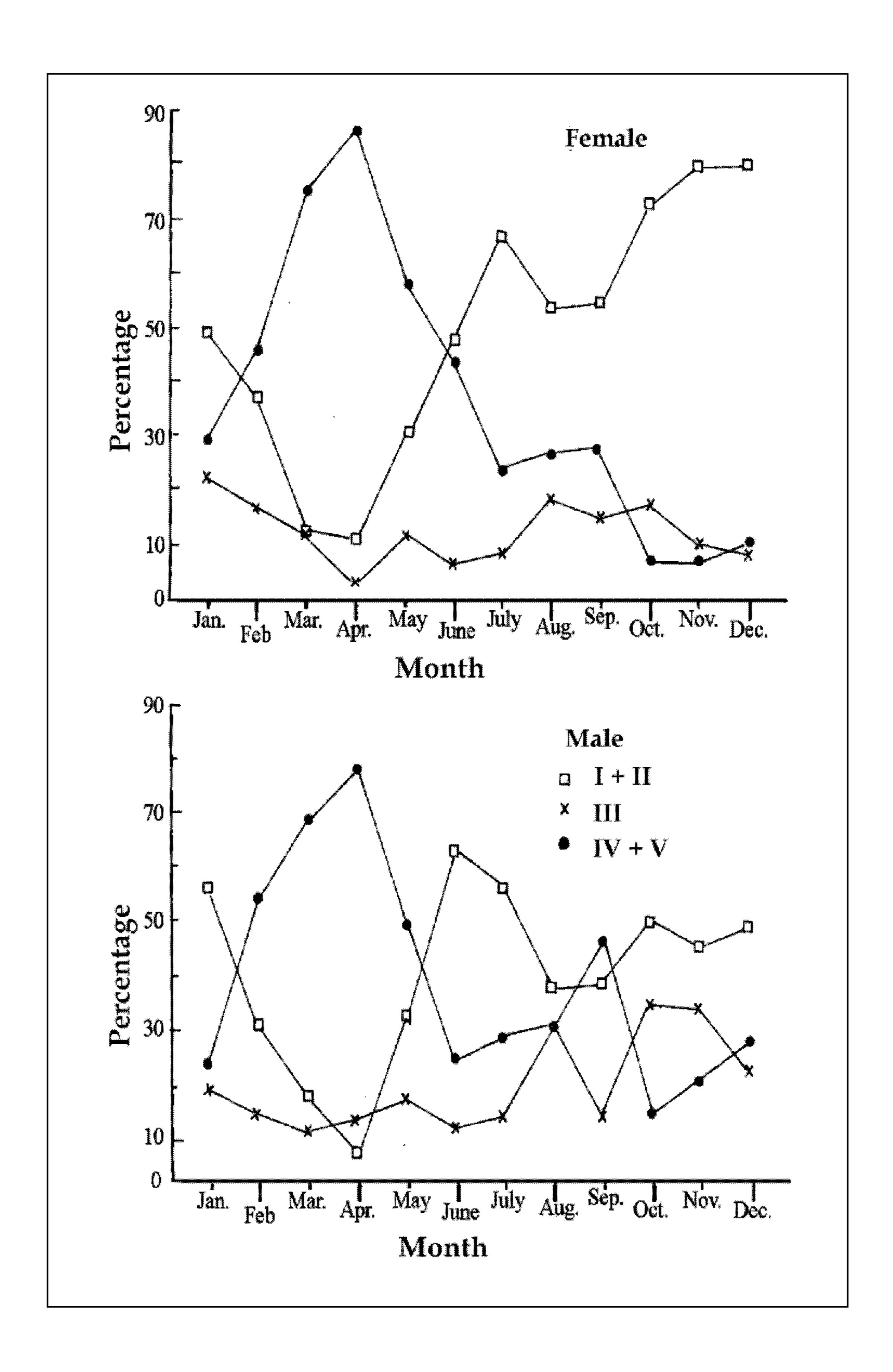


Fig 138 **Monthly gonad index of *M. kannume* (Aly 1993).**



Female
Percentage
90
70
50
30
10
0
Jan.
Feb
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
Month
Male
I + II
III
IV + V

Fig. 140 **Monthly percentage frequency of different maturity stages of *O. niloticus* (Adam 1994).**

pattern of egg diameter of *O. niloticus* (Fig. 141) was, to some extent, similar to that of gonad index (Fig. 136). There are two peaks (in May and September) for the average values of egg diameter. The egg diameter of *O. niloticus* is somewhat larger (2800 μ) than the egg diameter of *S. galilaeus* (2500-2800 μ) (Table 95 - Aly 1993).

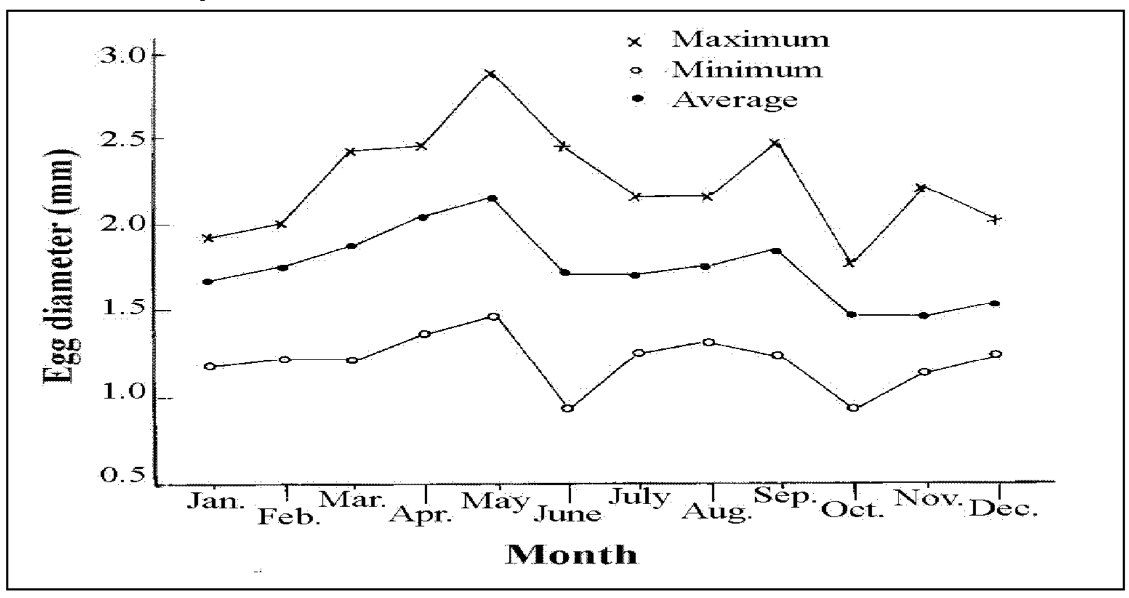


Fig. 141 **Minimum, maximum and average diameter of oldest eggs of *O. niloticus* in different months (Adam 1994).**

Table 95 **Diameter of mature ripe eggs of important fish species (Aly 1993).**

Species	Egg-diameter (μ)
Lates niloticus	600-775
Brycinus nurse	800-825
Alestes baremoze	935
Schilbe uranoscopus	800-825
Eutropius niloticus	850-1025
Hydrocynus forskalii	850-950
Labeo coubie	1000-1050
Labeo horie	1050-1200
Labeo niloticus	1050-1225
Synodontis serratus	1200-1225
Synodontis schall	1200-1260
Bagrus docmak	1350-1425
Mormyrus kannume	1925-2170
Mormyrus caschive	2100-2500

Oreochromis niloticus	2800
Sarotherodon galilaeus	2500-2800

First sexual maturity

The knowledge of size and age at the first sexual maturity of the commercial fish species is of utmost importance in the development and management of the fisheries of Lake Nasser. Studies by various investigators (Entz & Latif 1974, Latif *et al.* 1979, Abdel-Azim 1982, Aly 1993) on the sexual maturity of different fish species from Lake Nasser shows the smallest size of various fish species when their first maturity is attained (Table 96).

Table 96 **The smallest length of various fish species in Lake Nasser, attaining their first sexual maturity (Entz & Latif 1974, Latif *et al.* 1979, 1984b and c, Abdel-Azim 1982 and Aly 1993).**

Species	**Minimum length at first sexual maturity (cm)**	
	♂	♀
Oreochromis niloticus	23	26
Sarotherodon galilaeus	--	16
Hydrocynus forskalii	30.5	29.5
Brycinus nurse	4.5	6
Alestes baremoze	20	23
Mormyrus kannume	32	34.6
Mormyrus caschive	40	32.3
Mormyrus anguilloides	50	50
Petrocephalus bane	17	18
Labeo niloticus	53	55
Labeo coubie	35	36
Labeo horie	--	33
Barbus bynni	--	57
Bagrus docmak	--	60
Synodontis serratus	31	35
Synodontis schall	24	28
Eutropius niloticus	16	18
Lates niloticus	38	30

Fecundity

It is obvious that *O. niloticus* and *S. galilaeus* have the lowest values of fecundity, being mouth breeders, while *Lates niloticus* has the highest egg production (Table 97). The absolute fecundity ranges between 1.4 thousand, in *S. galilaeus* to 618.3 thousand in *Lates niloticus* (Table 97 A.) Also, the fecundity varies greatly with age as in *Mormyrus caschive* and *Mormyrus kannume* (Table 97B, Fig. 142). The fecundity of *Eutropius niloticus* and *Alestes baremoze* lies between that of *Tilapia* spp. and *Lates niloticus*. Thus, while the absolute fecundity ranges from 7.2 thousand for *Tilapia* spp. to 618.3 thousand for *Lates niloticus*, it ranges between 55 and 223.7 thousand eggs for age groups VI-VII (Table, 97 B) for *Eutropius niloticus* and *A. baremoze* (Latif *et al.* 1979).

As the fisheries of Lake Nasser is based on two major fish species i.e. *O. niloticus* and *S. galilaeus,* hence reference to various parameters of fecundity are referred to, based on studies by Aly (1993) and Adam (1994).

***Table 97 Absolute* fecundity (number of ovarian mature/ripe eggs) during the peak of spawning season of various fish species in Lake Nasser.**

A. Variation with length

Species	Standard length range (cm)	Average absolute fecundity (thousand)	Relative fecundity eggs/cm
Oreochromis niloticus	26-45	2.9-7.0	88-186
Sarotherodon galilaeus	17.5-34.5	1.4-7.2	80-209
Brycinus nurse	6.5-13.5	6.5-24.5	1000-1815
Eutropius niloticus	20-34	31-65	1425-1832
Alestes baremoze	24-42	28.5-223.7	1187-5326
Lates niloticus	27.8-51.5	89.3-618.3	3208-12006
Mormyrus kannume	34.6	0.6-7.8	25-152
Mormyrus caschive	32.3	0.5-5.8	19-120

B. Variation with age

Age group	*S. galilaeus*	*Oreochromis niloticus*	*Lates niloticus*	*Alestes baremoze*	*Eutropius niloticus*	*Mormyrus caschive*	*Mormyrus kannume*
I	3300	3516	--	--	--	--	--
II	4400	4170	139,000	--	--	--	--
III	4900	5175	262,000	28,500	30,500	1,730	1,601
IV	5600	6090	481,900	97,900	37,500	3,734	3,450
V	--	-	--	140,800	48,500	7,948	6,363
VI	--	-	--	206,600	55,000	11,138	--
VII	--	-	--	223,700	--	--	--

1. *Oreochromis niloticus*

For *O. niloticus* the following relationships were determined (Adam 1994):

Absolute fecundity

a. Fecundity versus length. The average number of eggs increased from 2485 to 7003 for the body length from 26 to 45 cm (Fig. 143). The relation between the two variables is as follows:

Log F = 0.5816 + 1.9948 Log L

(F = number of eggs, L = body length cm)

b. Fecundity versus weight . The average number of eggs increased from 2789 to 5729 for the body weight from 700 to 3500 g (Fig. 144). The relation between fecundity and body weight is as follows :

Log F = 2.2385 + 0.4321 Log W

(F = number of eggs; W = body weight)

c. Fecundity versus age. The average number of eggs increased from 3516 to 6090 for the age groups I to IV (Fig. 145). The relation is described by the following equation:

Log F = 3.5455 + 0.3796 Log A

(F = number of eggs, A = age of fish)

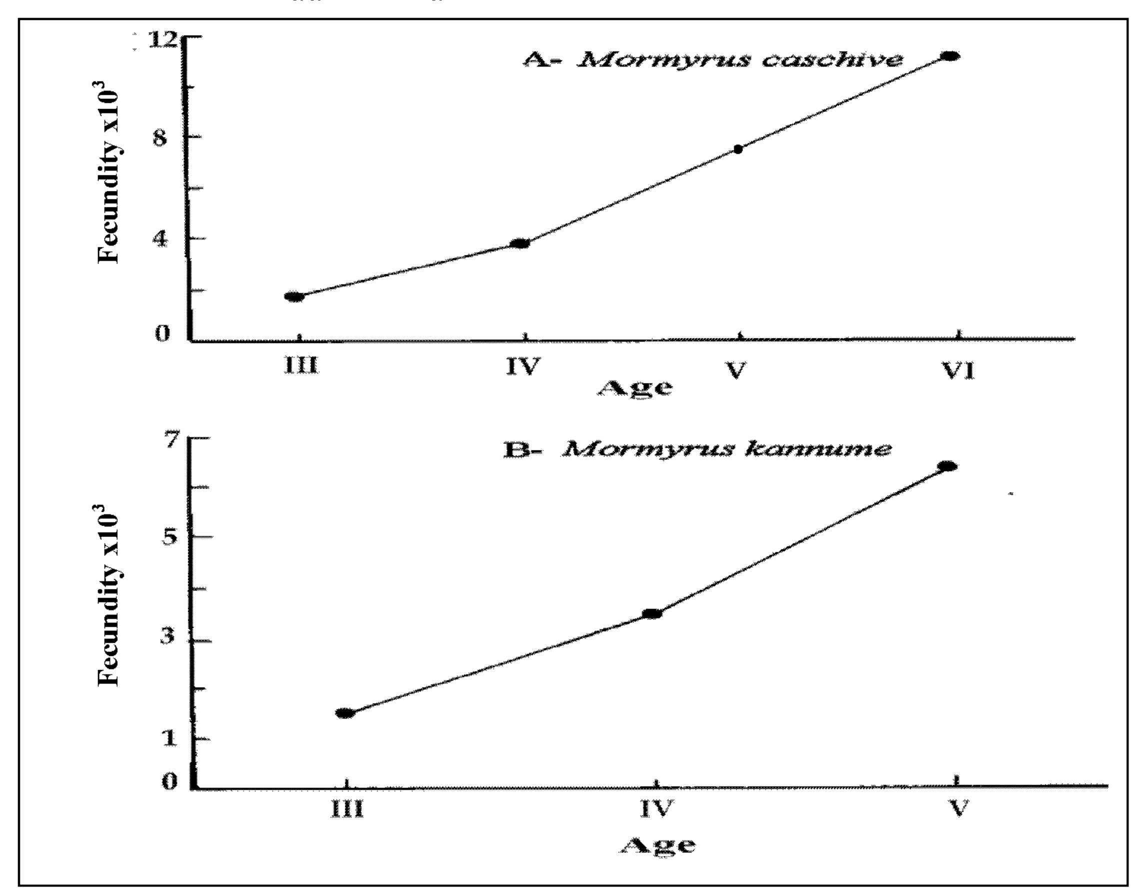


Fig. 142 **Fecundity variation with age of A:** ***Mormyrus caschive,*** **B:** ***Mormyrus kannume*** **(Aly 1993).**

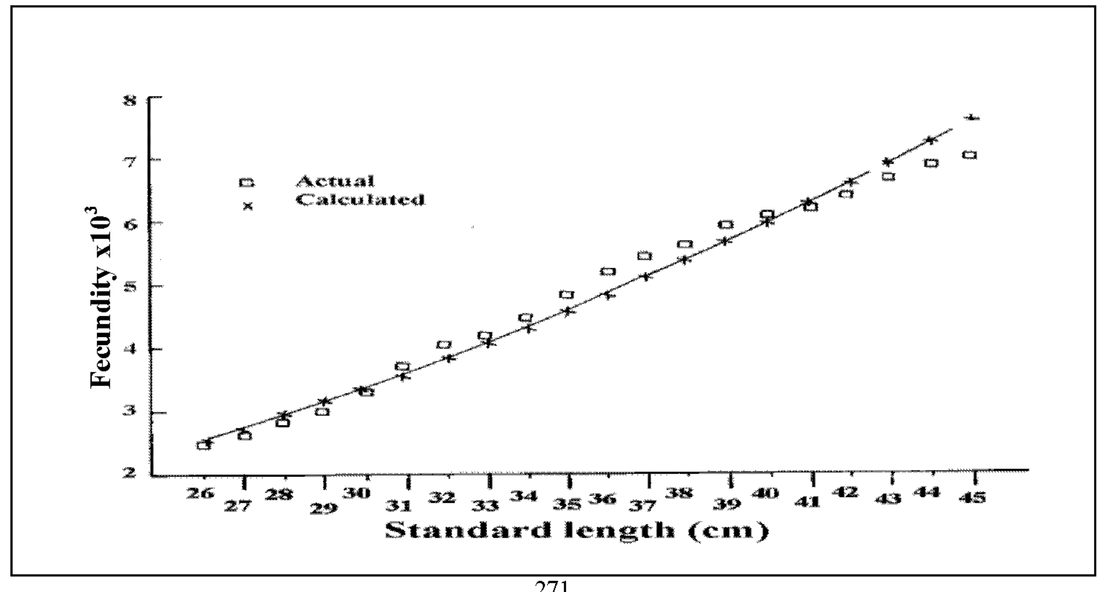


Fig. 143 **Variation of absolute fecundity with length of *O. niloticus* (Adam 1994).**

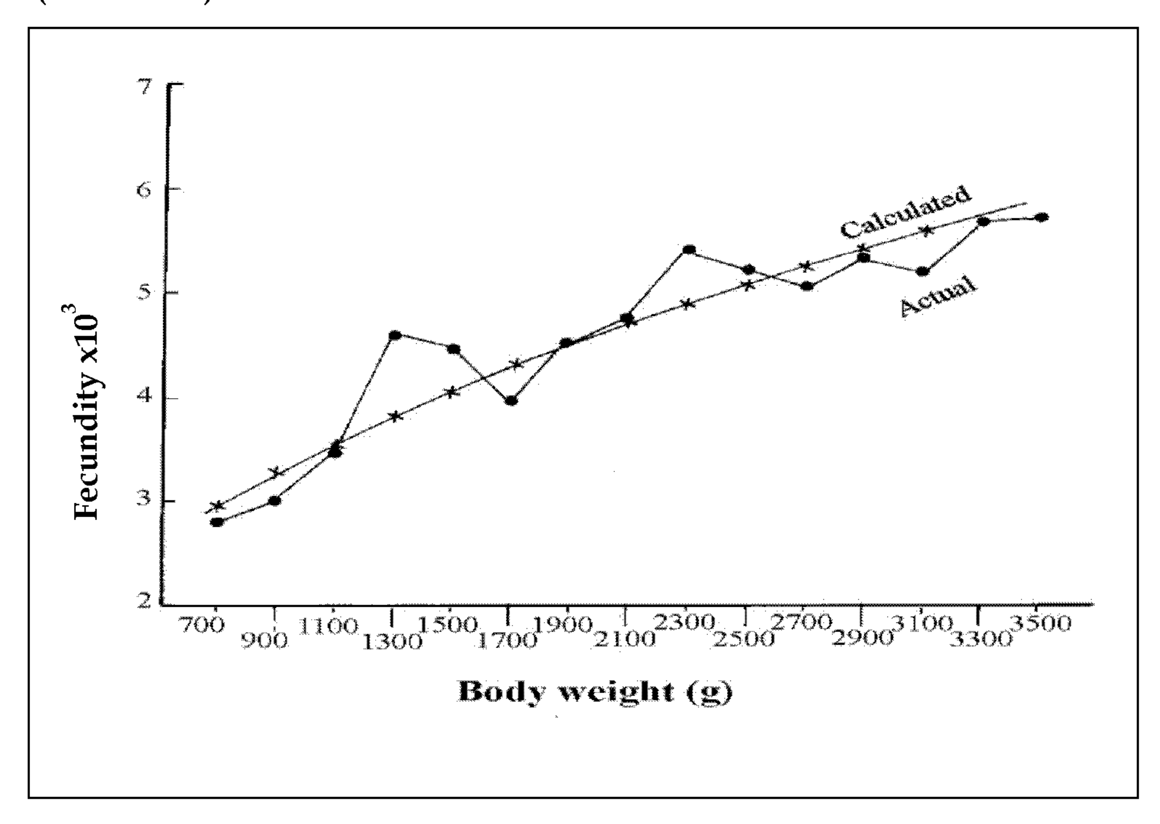


Fig. 144 **Variation of absolute fecundity with weight of *O. niloticus* (Adam 1994).**

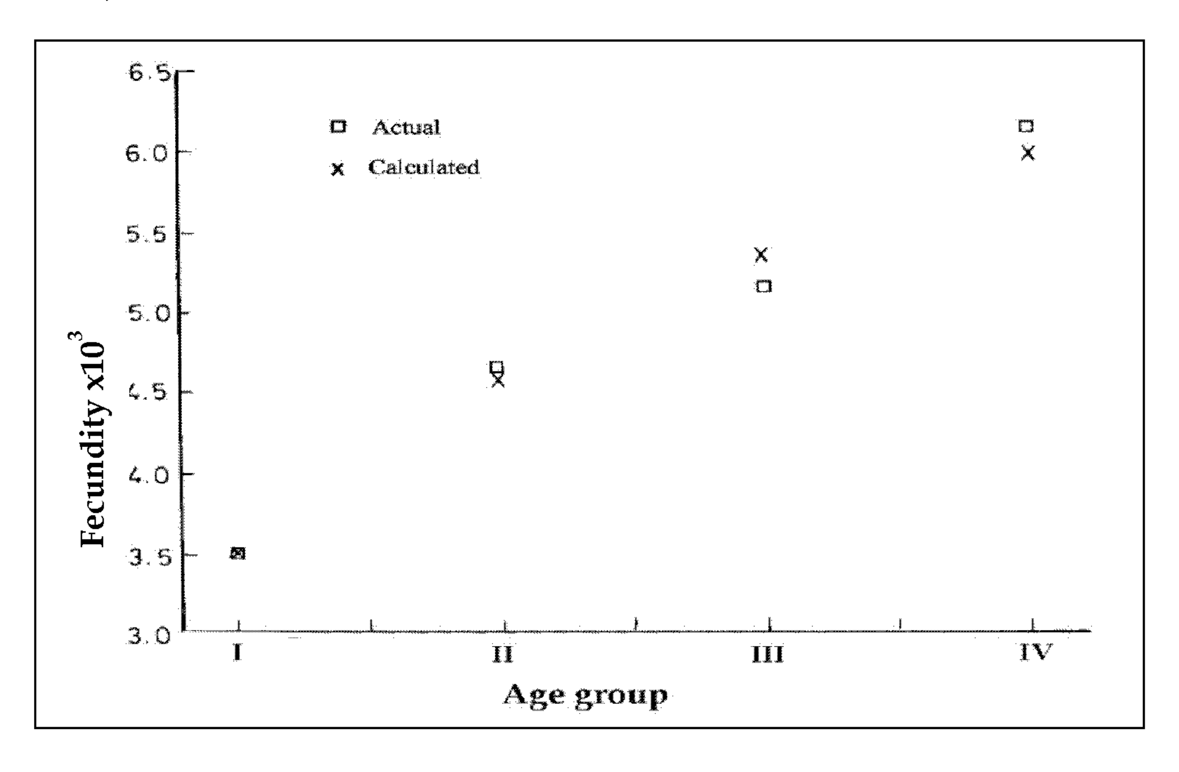


Fig. 145 **Variation of absolute fecundity with age of *O. niloticus* (Adam 1994).**

d. Fecundity versus gonad index. The average number of eggs ranged between 3205 and 6185 for the gonad index from 1.0 to 4.2 (Fig. 146). The relation is fit to the following equation:

Log F = 3.4959 + 0.4761 Log GI

(F= number of eggs, GI = average gonad index).

Adam (1994) concluded that the absolute fecundity of *O. niloticus* increased with length, weight, age and gonad index.

Relative fecundity

a. Relative fecundity versus length. The relative fecundity increases with the increase of body length and its value ranges between 88.32 and 186.06/cm for the body length range of 26 to 45 cm (Fig. 147). This relation is represented by the following equation :

Log RF = 0.1520 + 1.3032 Log L

(RF = relative fecundity, L= standard length).

b. Relative fecundity versus weight. The relative fecundity increases with the increase of body weight up to 1300 g, and its value ranges between 2.44 and 3.33 egg/g. For the body weight ranging from 1500 to 2500 g, the relative fecundity decreases progressively from 2.92 to 1.97 egg/g with the exception of average body weight 2300 g as it is 2.88 egg/g. The relative fecundity increases from 2.16 to 3.32 egg/g for body weight ranging from 2700 to 3500 g (Fig.148). The fluctuations of the relative fecundity with the body weight do not exhibit any particular pattern. The relation is described as follows:

Log RF = 0.4394 - 0.0045 Log W

(RF = relative fecundity, W = body weight)

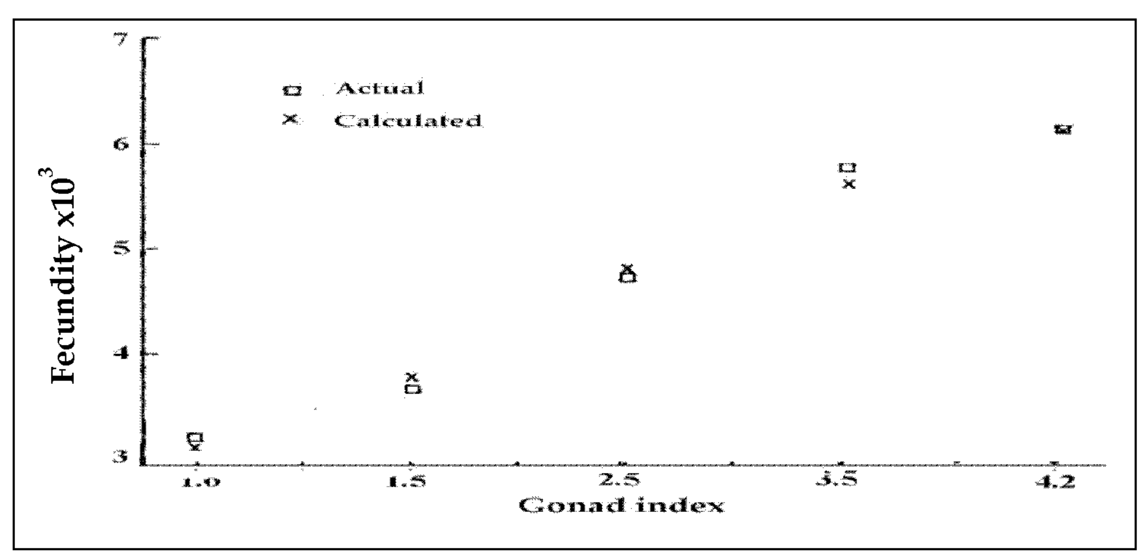


Fig. 146 **Variation of absolute fecundity with gonad index of *O. niloticus* (Adam 1994).**

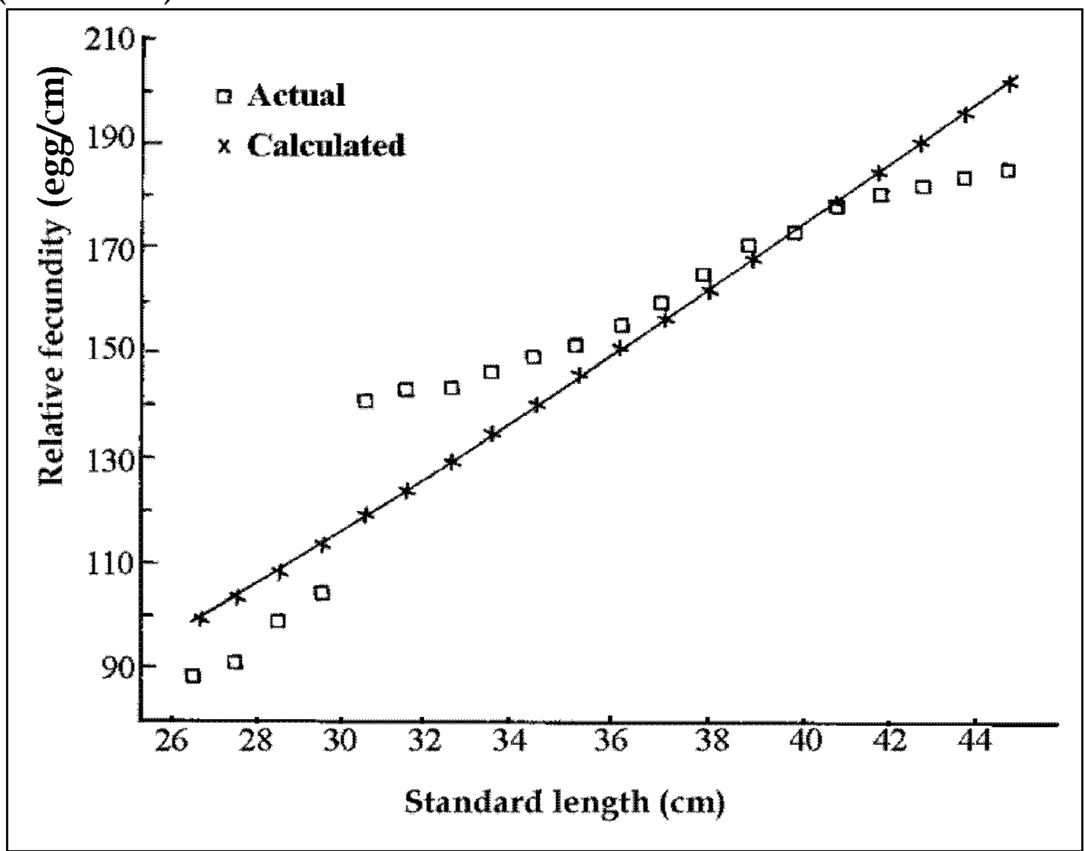


Fig. 147 **Variation of relative fecundity with length of *O. niloticus* (Adam 1994).**

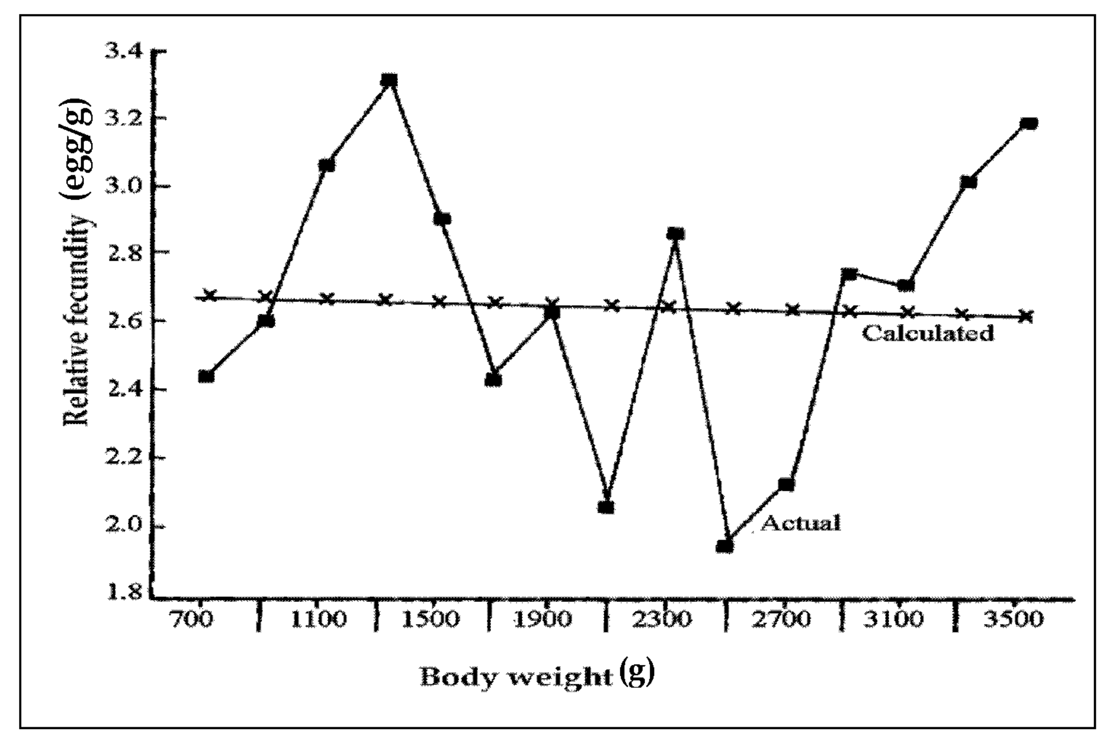


Fig. 148 **Variation of relative fecundity with weight of *O. niloticus* (Adam 1994).**

2. *Sarotherodon galilaeus*

Aly (1993) calculated the absolute fecundity for *S. galilaeus* as follows:

(a) Fecundity versus length. The average number of eggs increased from 1400 to 7200 for the body length from 17.5 to 34.5 cm (Table 97A).

(b) Fecundity versus age. The average number of eggs increased from 3300 to 5600 for the age groups I to IV (Table 97B).

CONCLUSIONS

The **food** and **feeding habits** of fish species in Lake Nasser may be divided into:

1. Periphyton-plankton feeders. a) *Oreochromis niloticus* which feeds on : periphyton (Chlorophyta, Cyanophyta and diatoms), phytoplankton (Chlorophyta, Cyanophyta, diatoms and Dinophyceae) and zooplankton (Cladocera, Rotifera, Ostracoda and Copepoda).

b) *Sarotherodon galilaeus* feeds on: Periphyton (Chlorophyta, Cyanophyta and diatoms), phytoplankton (diatoms, Chlorophyta and Cyanophyta) and zooplankton (copepods and cladocerans).

2. Zooplankton-insect feeders. a) *Brycinus nurse* which feeds on copepods, decapods, cladocerans, insect larvae and gastropods. (b) *Alestes baremoze* feeds on copepods, cladocerans, insects, gastropods and phytoplankton.

3. Omnivores including *Eutropius niloticus* which feed on: insect larvae, water beetles, Odonata, worms, freshwater shrimps, bivalves and fishes. *Synodontis* spp. feed on: animal food including fishes, worms, molluscs and insects, in addition to food of plant origin and phytoplankton. *Schilbe uranoscopus* feed on small fish, chironomid larvae, nymphs of Pleocoptera, copepods and cladocerans. Mormyrids feed on larvae and pupae of chironomids, nymphs of Odonata, Corixidae (water-bugs), larvae of Trichoptera, cladocerans, detritus, aquatic plants, diatoms, freshwater shrimps and fishes. *Labeo* spp. and *Barbus* spp., their food consists of diatoms, cyanophytes, worms and plant material.

4. Carnivores including *Lates niloticus* which feed mainly on fish, freshwater shrimps and insects. The percentage occurrence of fish increases with age. *Bagrus* spp. feed on fishes, freshwater shrimps, insects and molluscs. While, *Clarias gariepinus* and *Heterobranchus* spp. are bottom feeders feeding on fish, insects, molluscs and plant food. *Hydrocynus forskalii* feed on fishes, insects and freshwater shrimps.

It is to be noted that oligochaetes are always underestimated when investigating stomach contents of fish, as they are very readily digestible and leave no observable traces.

Some fish species, in Lake Nasser, are slender (as *Eutropius niloticus, Hydrocynus forskalii, Alestes baremoze)*, others have heavier bodies (as *Labeo niloticus, L. forskalii, Lates niloticus* and *Barbus bynni*) and still others as *Sarotherodon galilaeus* and *Oreochromis niloticus* have the heaviest weights.

The length-weight relationship and **condition factor** of the commercial fishes in Lake Nasser, calculated by different authors, are given. The growth rate in length of *O. niloticus* is higher than that of *S. galilaeus*. Growth rates of both tilapiine species are higher in the southern region of the lake than those inhabiting the northern region.

The difference in calculated weights between different fish species, even those belonging to the same genus is more prominent with weight than with length. *O. niloticus* of age group III has an average actual weight of 1866 g as compared with 971 g for *S. galilaeus.* The growth increment in weight for age-group I of *O. niloticus* is the lowest and increases progressively in the older ages up to age group IV. The average weights of *O. niloticus* are higher than those of *S. galilaeus.* For *S. galilaeus,* the calculated weight of age group I is nearly equal to that of *O. niloticus*; while those of age groups II and III are less than the calculated values for the same age groups in *O. niloticus*. The growth increment in weight of *S. galilaeus* is the lowest for age group I, then increases in age-group II and decreases in age-group III.

Comparing the calculated growth in length and weight of *O. niloticus* and *S. galilaeus* during the last two decades suggests a marked decrease in the growth rate of both tilapiine species during recent years. The effect of impoundment on the growth of both *Tilapia* spp. is discussed.

The calculated weights for different age-groups of 14 fish species in Lake Nasser are presented. There is a significant difference in growth between *Bagrus bajad* and *B. docmak*. The latter species grows faster and lives for longer age.

As for **reproduction** of fishes of Lake Nasser three main groups can be distinguished: -

a. Fishes which have prolonged spawning season mainly with two peaks during spring and autumn (*O. niloticus, S. galilaeus, Brycinus nurse* and *Lates niloticus*).

b. Summer spawners (*Alestes baremoze, Eutropius niloticus, Labeo coubie, Labeo horie, Barbus bynni, Mormyrus kannume* and *M. caschive*)

c. Winter spawners as *Labeo niloticus*

O. niloticus, S. galilaeus and Bagrus spp. are nest builders, while *Lates niloticus is* extremely different as it lays pelagic eggs. *Alestes baremoze* undergoes a spawning migration which coincides with flood as both sexes move upstream behind the Second Cataract and Amada, dwelling along the narrow part of the reservoir affected by the early washes of the flood thus inducing spawning.

Monthly percentage frequency of different maturity stages in *O. niloticus* (males and females) suggest multiple spawning with a maximum during March-May and September. *Sarotherodon galilaeus* spawns most of the year as mature fishes are encountered all the year round. Monthly variations of gonad index of the commercial fish species in Lake Nasser are shown, indicating the spawning season of these species.

Fish eggs vary in size from one species to another. The smallest are the pelagic eggs of *Lates niloticus* (600-775 μ) while the largest are those of *O. niloticus* (2800μ) and *S. galilaeus* (2500-2800 μ). The monthly variations in the size of the oldest ovarian eggs of *O. niloticus* are given, an indication of their spawning season which coincides with both gonad index and maturity stages.

The size at first sexual maturity of the commercial fish species in Lake Nasser is mentioned, *Bagrus docmak* being the longest (60 cm for females) and *Brycinus nurse* being the smallest as its first maturity is attained when 6 cm long.

The absolute fecundity ranges between 1.4 thousand in *S. galilaeus* to 618.3 thousand in *Lates niliticus.* Variations of absolute and relative fecundities with length, weight, age and gonad index for *O. niloticus* are given. For *S. galilaeus,* the absolute fecundity versus length and age are calculated.

One of the reasons that may account for the predominance of *S. galilaeus* over *O. niloticus* in Lake Nasser during the last decade, may be the competition for spawning sites as both species are nest builders and have a similar spawning behaviour. Furthermore, considering the gonad index, maturity stages and dominance of mature eggs shows that *S. galilaeus* may spawn throughout the whole year, while *O. niloticus* spawns 2-3 times with two peaks during March-May and August-September. In addition in *S. galilaeus* both parents are mouth brooders, while in *O. niloticus* females are the only mouth brooders.

Chapter 8
Fish Parasites and Diseases

Considerable attention has been given to fish parasites in Lake Nasser by various investigators, dating back to the seventies. Wannas (1977) recorded 10 genera of helminth parasites in his investigation in 1974 - 1976. During the last five years some tilapia fish procured from the Lake and sold in various fish markets in Cairo, were found to be harbouring a heavy infection of nematodes in the head and viscera. This caused panic among consumers and raised a lot of inquiries about their nature and how they affect public health. To stop worries of the consumers, the authorities took a decision to decapitate tilapias of Lake Nasser before selling them to the public, and until now, they are still sold decapitated, a fact that has had a great effect upon marketing of Lake fishes in general. Therefore many studies of the Lake fish parasites and their impact on public health have been conducted during the last twenty years.

PREVALENCE OF PARASITE INFECTION

Saoud & Wannas (1984), in their investigation during 1974 to 1976 on fish parasites of Lake Nasser, examined 850 fishes belonging to 19 species. They examined the fish for trematodes, cestodes, nematodes, aspidocotyleans and acanthocephalans. Their results are shown in Table 98 and can be summarized as follows :

General prevalence. 615 fishes out of 850 (72.4%) were positive for helminth infections. The positive hosts were infected with one or more groups of trematodes, cestodes, aspidocotyleans, nematodes and acanthocephalans. Prevalence of different groups arranged in their order of frequency was 26.6% for trematodes, 24.8% for acanthocephalans, 22.6% for nematodes, 11.7% for cestodes and 0.1% for aspidocotyleans.

Trematode infections. Digenetic trematodes have been reported in eight host species belonging to five genera. The hosts were *Barbus bynni, Bagrus bajad, B.*

docmak, Synodontis schall, S. serratus and *Tetraodon lineatus*. One type of metacercaria was found in *Oreochromis niloticus* and *Sarotherodon galilaeus*. Amongst infected fish, the highest prevalence of digenetic trematodes was recorded in *Bagrus bajad* (88.9%) while the lowest was found in *O. niloticus* (33.3 %).

Cestode infections. Cestodes were recorded from *Barbus bynni, Clarias gariepinus* and *Malapterurus electricus*. The highest prevalence was found in *Malapterurus electricus* (96%) while the lowest was recorded in *Clarias gariepinus* (5%).

Aspidocotylean infections. These parasites were very rarely seen, being only recorded in one fish species *Synodontis schall,* with a prevalence of 2.0%.

Nematode infections. These were recorded from 8 species belonging to 5 genera. The positive hosts include: *Labeo horie, L. coubie, Synodontis schall* and *S. serratus, Lates niloticus, O. niloticus* and *S. galilaeus* and *Hydrocynus forskalii*. The highest prevalence of nematodes was found in *Labeo horie* (75.0%) and the lowest in *Lates niloticus* (10.0%).

Acanthocephalan infections. These helminth parasites were reported from 7 species of fish, belonging to 5 genera. The fish hosts were: *Clarias gariepinus, Bagrus bajad, B. docmak,Lates niloticus, S. galilaeus, O. niloticus* and *Tetraodon lineatus*. The highest prevalence of acanthocephalans was found in *S. galilaeus* (100%) and the lowest in *Clarias gariepinus* (10.0%).

Saoud & Wannas (1984) determined the prevalence of the digenetic trematodes, aspidocotyleans as well as acanthocephalans collected from different fishes, that can be summarized as follows:

A. Digenetic trematode infections

1. ***Astiotrema*** **infections.** This genus was recorded only from *Tetraodon lineatus* without a single exception, all helminthologically positive fish were infected with this genus of trematodes.

2. ***Acanthostomum*** **infections.** This genus was found only in genus *Bagrus*. Its prevalence in the two infected *Bagrus* species, varied from 76.9% in *Bagrus docmak* to 87.5% in *Bagrus bajad*.

3. ***Allocreadium*** **infections.** This genus was recorded only from *Babrus bynni*. Its prevalence reached 58.2%.

4. ***Haplorchoides*** **infections.** This trematode genus was only found in genus *Bagrus*. Without a single exception, all examined fish of either *B. bajad* or *B. docmak* were infected with this trematode genus.

5. ***Basidiodiscus*** **infections.** This genus was only found in the genus *Synodontis*. Its prevalence was high, varying from 96.4% in *S. schall* to 100% in *S. serratus*.

6. *Sandonia* infections. This trematode genus was recorded only in genus *Synodontis*, with a prevalence of 96.4% in *S. schall* and 100% in *S. serratus*.

Table 98 **Prevalence of trematodes, cestodes, aspidocotyleans, nematodes and acanthocephalans in fishes of Lake Nasser (Saoud & Wannas 1984) (* Metacercariae).**

Species	No. Examined	Positive		Trematodes		Cestodes		Aspidocotylea		Nematodes		Acanthocephala	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
***Labeo horie* Heck.**	40	30	75.0	0	0	0	0	0	0	30	75.0	0	0
***Labeo coubie* Rüpp.**	20	14	70.0	0	0	0	0	0	0	14	70.0	0	0
***Barbus bynni* (Forsk.)**	60	55	91.7	32	53.3	50	83.3	0	0	0	0	0	0
***Clarias gariepinus* (Burch.)**	20	3	15.0	0	0	1	5.0	0	0	0	0	2	10.0
***Schilbe mystus* (L.)**	25	0	0	0	0	0	0	0	0	0	0	0	0
***Bagrus bajad* (Forsk.)**	45	45	100	40	88.9	0	0	0	0	0	0	5	11.1
***Bagrus docmak* (Forsk.)**	15	15	100	13	86.7	0	0	0	0	0	0	2	13.3
***Chrysichthys auratus* (Geoffro.)**	20	0	0	0	0	0	0	0	0	0	0	0	0
***Synodontis schall* (Bloch. & Sch.)**	50	45	90	27	54.0	0	0	1	2.0	32	64.0	0	0
***Synodontis serratus* Rüpp.**	10	7	70.0	6	60.0	0	0	0	0	3	30.0	0	0
***Malapterurus electricus* (Gm.)**	50	48	96.0	0	0	48	96.0	0	0	0	0	0	0
***Lates niloticus* (L.)**	100	100	100	0	0	0	0	0	0	10	10.0	95	95.0
***Oreochromis niloticus* (L.)**	60	58	96.7	20*	33.3*	0	0	0	0	10	16.7	58	96.7
***Sarotherodon galilaeus* (Arf.)**	40	40	100	25*	62.5*	0	0	0	0	8	20.0	40	100
***Tetraodon lineatus* L.**	75	70	93.3	63	84.0	0	0	0	0	0	0	9	12.0
***Mormyrus kannume* (Forsk.)**	50	0	0	0	0		0	0	0	0	0	0	0
***Mormyrus cachive* L.**	50	0	0	0	0	0	0	0	0	0	0	0	0
***Hydrocynus forskalii* (Cuv.)**	100	85	85.0	0	0	0	0	0	0	85	85.0	0	0
***Alestes dentex* (L.)**	20	0	0	0	0	0	0	0	0	0	0	0	0
Total	**850**	**615**	**72.4**	**226**	**26.6**	**99**	**11.7**	**1**	**0.1**	**192**	**22.6**	**211**	**24.8**

***Clinostomum* (metacercaria) infections.** This metacercarial stage of the genus *Clinostomum* was found in tilapiine fishes. All infected fish had this metacercaria. The prevalence of infection was 27.9%. Mohamed & Sahlab (1993) found that the intensity of infection was up to 19 cysts in a fish. They were recovered from the branchial organs, eye sockets and pharynx, where they were localized as hypodermic cysts: whitish yellow in colour, of pea-sized, and embedded in tissues or attached free. The average size of each cyst was up to 5 mm in diameter.

B. Aspidocotlean infections

***Aspidogaster* infections**. An infection with this genus had been found only in a single specimen of *Synodontis schall* out of 50 specimens examined.

C. Acanthocephalan infections

1. ***Acanthosentis* infections**. This genus was only recorded from tilapiine fish. All infected *O. niloticus* and *S. galilaeus* had this genus of Acanthocephala. The intensity of infection was at its maximum in summer and reached a minimum in winter. The number of parasites per fish ranged from 8 to 23 in summer, while the corresponding figure for winter was 3 to 7.

2. ***Paragorgorhynchus* infections.** A new species of this genus (*P. aswanensis*) was described for the first time by Saoud & Wannas (1990) in Lake Nasser. This species was recorded from five fish species belonging to four genera including *Lates niloticus, Bagrus docmak, B. bajad, Tetraodon lineatus* and *Clarias gariepinus*. The highest prevalence amongst infected fish was 95% in *Lates niloticus* while the lowest was 11.1% in *Bagrus bajad*, 13.3% in *B. docmak* and 12.8% in *Tetraodon lineatus*. The intensity of infection also varied in different fish genera, being 87-200 per fish in *Lates niloticus*, 9-22 in *Tetraodon lineatus*, 4 -15 in *Bagrus bajad* and *B. docmak* and 4 - 7 in *Clarias gariepinus*.

The worms collected from *Lates niloticus* were larger in size than those from other hosts. Also the number of eggs in female worms, used as an indication of fertility, was highest in *Lates niloticus* compared to other hosts. This would indicate that *Lates niloticus* is a more favourable host of *P. aswanensis* than the other hosts.

In another more detailed survey of the helminth parasites in Lake Nasser, El-Naffar *et al.* (1983) examined 4733 fishes, belonging to 30 species. Out of the total number examined, 2645 (55.88%) were found to harbour one or more species of parasites, 403 (8.5%) were found harbouring trematodes, 220 (4.65%) harboured cestodes, 2256 (47.66%) harboured nematodes and 498 (10.52%) harboured acanthocephalans (Table 99). The highest prevalence of infestation with trematodes occurred in *Tetraodon lineatus* (92%), while the maximum prevalence of cestode parasites was 65.7% in *Clarias anguillaris*. The maximum prevalence with nematode parasites was found in *Hydrocynus forskalii* and *H. vittatus* (95.2% and 94%, respectively). The maximum prevalence of acanthocephalans was 80% in *Lates niloticus*. El-Naffar *et al.* (1983) did not record any helminth parasite in *Anguilla anguilla, Mormyrus caschive, M. kannume, Chrysichthys auratus, C. rueppelli* and *Malapterurus electricus*, thus, confirming the previous finding of Saoud & Wannas (1984) in 1974 - 1976.

El-Naffar *et al.* (1983) recorded nine trematode species in Lake Nasser (Table 100), including a new species *Astiotrema lazeri*. This species is a rare parasite collected from the intestine of *Clarias gariepinus*. Out of 50 fish examined, only one (2%) was found harbouring this species (*Astiotrema lazera*)

and the number of collected parasites was five (El-Naffer *et al.*, 1984a). The latter authors also recorded 8 species of nematodes, three species of acanthocephalans and five species of cestodes including a new species: *Marsypocephalus aegyptiacus*. The latter parasite is a rare species collected from the intestine of *Clarias anguillaris*. Fifty fish were examined, but only four cestodes were collected from a single host (El-Naffar *et al.* 1984b).

Table 99 **The relative prevalence of helminths in different species of fish examined (El-Naffar *et al.* 1983).**

FISH Species	Parasites										
	Total			Trematodes		Cestodes		Nematodes		Acanthocephalans	
	Examined	Positive									
	No.	No.	%	No.	%	No.	%	No.	%	No.	%
Anguilla anguilla	3	-	-	-	-	-	-	-	-	-	-
Mormyrus cachive	50	-	-	-	-	-	-	-	-	-	-
Mormyrus kannume	65	-	-	-	-	-	-	-	-	-	-
Hydrocynus forskalii	500	476	95.2	-	-	-	-	467	95.2	-	-
Hydrocynus vittatus	300	282	94	-	-	-	-	282	94	-	-
Hydrocynus brevis	300	270	90	-	-	-	-	270	90	-	-
Brycinus nurse	300	206	68.66	-	-	-	-	206	68.66	-	-
Alestes dentex	100	45	45	-	-	-	-	45	45	-	-
Alestes baremoze	100	10	10	-	-	-	-	10	10	-	-
Labeo niloticus	100	45	45	45	45	-	-	-	-	-	-
Labeo horie	150	23	15.33	23	15.33	-	-	-	-	-	-
Labeo coubie	150	20	13.33	20	13.33	-	-	-	-	-	-
Barbus bynni	100	66	66	38	38	54	54	7	7	-	-
Clarias anguillaris	35	28	80	12	34.28	23	65.71	1	2.85	-	-
Clarias gariepinus	50	41	82	22	44	31	62	3	6	-	-
Bagrus bajad	150	110	73.33	1000	66.66	-	-	64	42.65	-	-
Bagrus docmak	200	150	75	120	60	-	-	98	49	35	17.5
Chrysichthys auratus	100	-	-	-	-	-	-	-	-	-	-
Chrysichtys rueppelli	100	-	-	-	-	-	-	-	-	-	-
Synodontis schall	200	70	35.5	-	-	65	32.6	57	26.5	-	-
Synodontis serratus	150	52	34.66	-	-	47	31.33	40	26.66	-	-
Schilbe(Eutropius) niloticus	200	8	4	-	-	-	-	8	4	-	-
Schilbe (S.) mystus	150	70	46.66	-	-	-	-	70	46.66	-	-
Schilbe (S.) uranoscopus	200	85	42.5	-	-	-	-	85	42.5	-	-
Malapterurus electricus	5	-	-	-	-	-	-	-	-	-	-
Lates niloticus	300	260	86.66	-	-	-	-	260	86.66	240	80
Oreochromis niloticus	300	140	64.65	-	-	-	-	117	39	137	45.66
Sarotherodon galilaeus	200	100	50	-	-	-	-	92	46	86	4.3
Tilapia zillii	150	65	43.33	-	-	-	-	65	43.33	-	-
Tetraodon lineatus	25	23	92	23	92	-	-	-	-	-	-
Total	**4733**	**2645**	**55.88**	**403**	**8.51**	**220**	**4.65**	**2256**	**47.66**	**498**	**10.33**

Table 100 **The relative prevalence of helminth parasites in different species of fish from Lake Nasser (El-Naffar *et al.* 1983). Plates 50 to 62.**

Fish species	Parasites	No. of fish examined	Positve No.	Positve %	No. of Parasites per inf.	Mean /fish
	TREMATODA					
Labeo niloticus	*Nematobothrium labeonis*	100	45	45	2 - 6	(3)
Labeo horie	*Nematobothrium labeonis*	150	23	15.3	2 - 6	(4)
Labeo coubi	*Nematobothrium labeonis*	150	20	13.3	2 - 6	(4)
Barbus bynni	*Allocreadium aswanensis*	100	38	38	5 -14	(9)
	Allocreadium bynni	100	26	26	3 - 4	(3)
Clarias anguillaris	*Pristotrema clarii*	35	12	34.29	4 - 5	(4)
Clarias gariepinus	*Astiotrema lazeri*	50	1	2	5	(5)
	Orientocreadium lazeri	50	1	2	2	(2)
	Pristotrema clarii	50	20	40	6- 8	(7)
Bagrus bajad	*Acanthostomum spiniceps*	150	72	48	9-15	(12)
	Acanthostomum absconditum	150	50	33.3	7-17	(10)
Bagrus docmak	*Acanthostomum spinceps*	200	83	41.5	7-11	(9)
	Acanthostomum absconditum	200	90	45	7-15	(11)
Tetraodon lineatus	*Astiotrema impletum*	25	23	92	5-26	(14)
	NEMATODA					
Hydrocynus forskalii	*Philometroides hydrocyonae*	500	476	95.2	12-23	(7)
	Rhabdochona aegyptiacus	500	48	9.6	1-4	(3)
	Amplicaecum sp. (Larvae)	500	315	63	20-34	(25)
Hydrocynus vittatus	*Philometroides hydrocyonae*	300	282	94	10-17	(14)
	Rhobdochona aegyptiacus	300	35	11.6	3-5	(4)
	Amplicaecum sp. (Larvae)	300	168	56	12-25	(16)
Hydrocynus brevis	*Philometroides hydrocyonae*	300	270	90	9-20	(15)
	Rhabdochona aegyptiacus	300	36	12	3-4	(4)
	Amplicaecum sp. (Larvae)	300	49	16.3	7-15	(9)
Brycinus nurse	*Amplicaecum* sp. (Larvae)	300	206	68.66	5-15	(7)
Alestes dentex	*Amplicaecum* sp. (Larvae)	100	45	45	6-15	(12)
Alestes baremoze	*Amplicaecum* sp. (Larvae)	100	10	10	8-10	(8)
Barbus bynni	*Cucullanus barbi*	100	7	7	2-5	(3)
Clarias gariepinus	*Amplicaecum* sp. (Larvae)	50	3	6	12-15	(12)
Clarias anguillaris	*Amplicaecum* sp. (Larvae)	35	1	2.85	10	(10)
Bagrus bajad	*Thwaitia bagri*	150	14	9.3	3-5	(3)
	Amplicaecum sp. (Larvae)	150	64	42.6	8-22	(15)
Bagrus docmak	*Amplicaecum* sp. (Larvae)	200	98	49	14-25	(17)
Synodontis schall	*Cithariniella citharini*	200	57	28.5	6-20	(14)
Synodontis serratus	*Cithariniella citharini*	150	40	26.66	5-17	(10)
Schilbe niloticus	*Amplicaecum* sp. (Larvae)	200	8	4	6-10	(10)
Schilbe mystus	*Amplicaecum* sp. (Larvae)	150	70	46.66	7-23	(20)
Schilbe uranoscopus	*Amplicaecum* sp. (Larvae)	200	85	42.5	8-20	(15)
Lates niloticus	*Dichelyne fossor*	300	52	17.3	3-8	(5)
	Philometroides sp.	300	4	1.3	2-6	(4)
	Amplicaecum sp. (Larvae)	300	235	78.33	15-70	(41)
Oreochromis niloticus	*Amplicaecum* sp. (Larvae)	300	117	19	3-8	(5)
Sarotherodon galilaeus	*Amplicaecum* sp. (Larvae)	200	92	46	2-5	(3)
Tilapia zillii	*Amplicaecum* sp. (Larvae)	150	65	43.33	3-5	(3)
	CESTODA					
Barbus bynni	*Caryophyllaeus laticeps*	100	39	39	3-10	(5)
	Bothriocephalus barbus	100	15	15	3-4	(3)
Clarias gariepinus	*Proteocephalus sulcatus*	50	30	60	6-10	(7)
Clarias anguillaris	*Marsypocephalus aegyptiacus*	50	1	2	4	(4)
Synodontis schall	*Proteocephalus sulcatus*	35	23	65.71	6-10	(8)
Synodontis serratus	*Wenyonia virilis*	200	65	32.5	5-41	(14)
	Wenyonia virilis	150	47	31.3	3-28	(11)
	ACANTHOCEPHALA					
Bagrus docmak	*Neoechinorhynchus* sp.	200	35	17.5	3-5	(3)
Lates niloticus	*Tenuisentis niloticus*	300	240	80	7-16	(12)
Oreochromis niloticus	*Acanthosentis tilapiae*	300	137	45.66	3-10	(8)
Sarotherodon galilaeus	*Acanthosentis tilapiae*	200	86	43	4-7	(5)

On dealing with the habitat of the parasites in different organs in their hosts, El-Naffar *et al.* (1983) reported that the highest percentage (92.9%) of trematode parasites occurred in the intestine, while the lowest (7.06%) was in the orbital cavity of the eye. All the cestodes and acanthocephalans were found only in the intestine (100%). Regarding the nematodes, the highest percentage (59.55%) occurred in the muscles, followed by 40.54% in the fins.

In addition to fish parasites mentioned by El-Naffar *et al.* (1983) and Saoud & Wannas (1984), Al-Bassel (1990) recorded 4 more parasitic trematodes: *Cynodiplostomum* metacercariae from the muscles of *S. galilaeus* and *Clarias gariepinus, Prohemistomum* metacercariae from the muscles of *C. gariepinus; Metagonimus* metacercariae from the muscles of *Schilbe mystus,* and *Glossidium pedatum* from the intestine of *C. gariepinus.* He also recorded two cestodes: *Polyonchobobothrium clarias* from the intestine of *Clarias gariepinus* and *Proteocephalus pentastoma* from the intestine of *Mormyrus kannume;* as well as one nematode *Procamallanus laeviconchus* from the intestine of *C. gariepinus;* and one acanthocephalan *Paragorgorhynchus chariensis* from the intestine of *Lates nilotics.*

In 1992 Mohamed *et al.* (1994) isolated another two species of acanthocephalans from Lake Nasser fish, namely *Paragorgorhynchus albertianum* and *Acanthocephalus* sp. The prevalence of infestation in *Lates niloticus* was 85% with an intensity of 19 worms/microscopic field. The acanthocephaliasis was pronounced and manifested by heavy intestinal infestation with thorny headed worms which were strongly attached to the intestinal mucosal membrane using their proboscis' hooks. The histopathological alterations were moderate to severe inflammatory reactions characterized by hypertrophy, hyperplasia, and completely necrotic and sloughing areas in the intestinal mucosa with leucocytic infiltration, mainly by lymphocytes.

On the other hand, Garo (1993) in her study on parasitic nematodes of some locally consumed fish in Egypt, recorded two species in fish from Lake Nasser viz. *Cucullanus barbi* Baylis, 1923 and *Contracaecum* sp. Garo (1993) found 42 adult worms of *C. barbi* in the intestine of the fish hosts *Barbus bynni, Mormyrus kannume, M. caschive* as well as *Lates niloticus,* but El-Naffar *et al.* (1983) encountered them from *Barbus bynni* only. The juveniles of *Contracaecum* sp. were encountered in the branchial cavity and mainly in the sinus venosus of *Sarotherodon galilaeus.* However, Al-Bassel (1990) collected such juveniles from the abdominal and branchial cavities of a variety of fish species from Lake Nasser, viz. *Clarias gariepinus, Barbus bynni, Lates niloticus, Synodontis schall, Sarotherodon galilaeus* and *Mormyrus kannume.* On the other hand, Garo (1993) claimed that Ibrahim & Mahmoud (1988) misidentified such juveniles as belonging to *Amplicaecum* sp. when they were studying their histopathological effect on some Nile fish. Easa *et al.* (1989) recorded the infection of both tilapiine species in Lake Nasser by the nematode larvae type *Amplicaecum* (Baylis, 1920). The parasites were accumulated in the pericardial cavity and sinus venosus of the heart at a density of 3-15 worm larvae per infected fish.

SINGLE (PURE) INFECTION WITH ONE GENUS OF TREMATODA

Saoud & Wannas (1984) reported that in Lake Nasser the total prevalence of pure infections with one genus of trematodes was almost twice that of double infections with two genera of trematodes, being 65.5 and 34.5%, respectively. The lowest prevalence with one genus of trematodes was recorded from *Bagrus bajad* (12.5%) and *B. docmak* (23.0%), while in other species of fish that prevalence was 100% in all cases.

Pure infections with one trematode genus recorded from five genera of fishes with eight species are as follows:

1. Genus *Astiotrema*. The prevalence of this genus in pure infections is very high (100%) in *Tetraodon lineatus*.
2. Genus *Haplorchoides*. The prevalence of pure infections in this genus is low (12.5%) in *Bagrus bajad* but high in *Bagrus docmak,* it was 23%.
3. Genus *Allocreadium.* The prevalence of pure infections in this genus is 100% in *Barbus bynni*.
4. Genus *Clinostomum* (metacercaria). The metacercarial stage of genus *Clinostomum* is recorded in 100 % of infected *O. niloticus* and *S. galilaeus*.

SIMULTANEOUS INFECTIONS WITH TWO GENERA OF TREMATODES

Simultaneous infections of some fishes with two genera of trematodes have been encountered by Saoud & Wannas (1984) in Lake Nasser. The total prevalence of double infections with trematode genera was 34.5%. These infections were recorded from two genera of fishes with four species. The following combinations of trematode genera have been found in such infections:

1- *Acanthostomum* + *Haplorchoides.* The prevalence of this combination was 76.9% in *Bagrus docmak* and 87.5 % in *Bagrus bajad*. This combination was more commonly seen in young fish than in older ones.

2- *Basidiodiscus* + *Sandonia:* this combination was recorded from all infected *Synodontis schall* and *S. serratus*. In no single case was either parasite found alone in the infected host.

DISPERSION OF PARASITES WITH THE AGE OF HOST

In Lake Nasser, some parasites showed a significant dispersion relation throughout the age of their host, including the prevalence and intensity of infection (Saoud & Wannas, 1984). They found this relation in many examples such as:

1. The prevalence and intensity of infection with the acanthocephalan species *Paragorgorhynchus aswanensis* in *Lates niloticus* increased with the age of fish.
2. The prevalence and intensity of infection with the acanthocephalan *Acanthogyrus* (*Acanthosentis*) (Verma & Datta 1929) in *O. niloticus* and *S. galilaeus* increased with age of fish.

3. The prevalence and intensity of infection with trematodes of sub-genus *Acanthostomum* (*Atrophocaecum*) Bhalero, 1940 in *Bagrus bajad* and *Bagrus docmak* decreased with the age of fish.

4. The prevalence of genus *Haplrochoides* Chen, 1949, was almost constant throughout the age of fishes of genus *Bagrus,* but the intensity of infection decreased with the increase of age. The same result was obtained with trematodes of genus *Astiotrema* Looss, 1900 from *Tetraodon lineatus.*

5. The infection of *Bagrus bajad, B. docmak, Tetraodon lineatus* and *Clarias gariepinus* with Acanthocephala of the species *Paragorgorhynchus aswanensis* was only recorded from older fish; no young fish were infected.

6. The prevalence and intensity of infection with nematodes increased with age in *Hydrocynus forskalii.*

DISEASES FROM FISH PARASITES AND MEASURES FOR THEIR PRVENTION

Disease from *Contracaecum* arises in humans at a density of 3-15 worm larvae per infected fish when improperly cooked, smoked, or raw fish are eaten (Cheng 1976). Medical literature contains annually over 3000 cases of nematode infection only from Japan (Fontaine 1985). Generally, the risk of infection from nematodes is reduced when fish are gutted soon after capture; salting may also decrease prevalence. However, neither smoking nor light salting of fish normally affect larvae. Freezing at -20 °C for 72 hours or heating above 55 °C for 10 seconds kills adult parasites (Khalil 1969). Because infection of fillets may be related to body cavity burdens, subsamples that cannot be immediately frozen or gutted could be checked for numbers of parasites. If the number exceeds 15, the fish should be banned for human consumption (Bier *et al.* 1987).

Clinostomiasis (yellow grub disease) is caused when humans ingest *Clinostomum* metacercariae. Mohamed & Sahlab (1993) recorded *Clinostomum* metacercariae from both tilapiine species procured from Lake Nasser. Ilan Paperna (1980) reported that clinostomiasis is a zoonotic disease of which few cases were recorded in the Near East inducing laryngopharyngitis (Halzuun) as a result of ingesting inadequately cooked infected fish with *Clinostomum complanatum.* Cases of acute clinostomiasis (Halzuun-like disease) caused by *Clinostomum complanatum* metacercariae were recorded by various investigators (Umezaki *et al.* 1990, Yohimura *et al.* 1991, Chung *et al.* 1995). It is worth mentioning that *Clinostomum complanatum* is a common parasite of both tilapiine species in Lake Nasser. Hence, it is recommended that the fish is gutted soon after capture and adequately cooked before consumption. Until now no cases of clinostomiasis have been recorded in Egypt.

CONCLUSIONS

Examination of 850 fishes in 1974 - 1976 (Saoud & Wannas 1984) belonging to 19 fish species from Lake Nasser revealed that 72.4% of the fishes were infected by helminth parasites including trematodes, cestodes,

aspidocotyleans, nematodes and acanthocephalans. The prevalence of infections were 26.6, 11.7, 2.0, 22.6, and 24.8% respectively.

In another survey of helminth parasites (El-Naffar *et al.* 1983) 4733 fish, belonging to 30 species, were examined. Out of the total number examined, 2645 (55.9%) were found to harbour one or more species of parasites. Nine trematode species were recorded, including a new species, *Astiotrema lazeri* from the intestine of *Clarias gariepinus.* The authors recorded also 8 species of nematodes, 3 species of acanthocephalans and 5 species of cestodes, including a new species, *Marsypocephalus aegyptiacus,* from the intestine of *Clarias gariepinus.*

In 1988/1989, El-Bassel (1990) examined 400 fishes belonging to 8 species in Lake Nasser, and revealed that about 88% of the fishes were infected by helminth parasites. He recorded 21 species; 9 trematodes, 4 cestodes, 5 nematodes and 3 acanthocephalans.

Trematode parasites were recorded in *Bagrus* spp., *Labeo* spp., *Clarias* spp, *Synodontis* spp., *Barbus bynni, Tetraodon lineatus* and one type of metacercaria in both *O. niloticus* and *S. galilaeus.* Cestode infections were recorded from *Barbus bynni, Synodontis* spp. *Clarias* spp. and *Malapterurus electricus.* Nematode infections were found in *Labeo* spp., *Alestes* spp., *Barbus bynni, Clarias* spp., *Bagrus* spp. *Synodontis* spp., *Lates niloticus* and both tilapiine species, *Hydrocynus* spp. and *Schilbe* sp. Acanthcephalan infections were recorded in *Clarias gariepinus, Bagrus* spp., *Lates niloticus,* both tilapiine species and *Tetraodon lineatus.* Aspidocotylean infection was rarely observed and has been recorded in *Synodontis schall, Bagrus docmak, Lates niloticus* and both tilapiine species.

Oreochromis niloticus and *Sarotherodon galilaeus* were infected by the same parasites i.e. *Clinostomum complanatum* (metacercaria), *Clinostomum* spp., *Acanthogyrus tilapiae* and larvae of *Amplicaecum*. In only *S. galilaeus* infection with *Contracaecum* (as larvae) was recorded. Other parasites may be found later with further investigations.

At least 40 helminth parasites were recorded from the common fish species from Lake Nasser. The intensity of infection may vary with season and age. It was found that the total prevalence of pure infection with one genus of trematodes was almost twice that of double infection with two genera.

Contracaecum (as larvae)-which was misidentified as *Amplicaecum* in some fish species - was found in the abdominal and branchial cavities of *Sarotherodon galilaeus, Lates niloticus, Barbus bynni, Clarias gariepinus, Synodontis schall* and *Mormyrus kannume.* Although no human infection with *Contracaecum* has been reported from Egypt, cases of this infection were reported from other countries as Japan. Hence as a precautionary measure to kill the parasite, fish must be gutted soon after capture, well cooked or properly salted. Freezing at -20 °C for 72 hours or heating above 55 °C for 10 seconds will kill adult

parasites. Neither smoking nor light salting of fish normally affects *Contracaecum* larvae.

Chapter 9
Fisheries

Assessment of Lake Nasser fisheries is required for better development and management of the resources on which the fishing is based. This requires a certain preliminary assessment of the level of exploitation of the fishery relative to its potential. Furthermore, details of the biological and ecological constraints to the resource are needed for the effective management and monitoring.

As a matter of fact, remarkable changes both in environment and fishery have been occurring in Lake Nasser since the construction of the High Dam. Unfortunately, there is a lack of adequate scientific knowledge and data on the present fish stocks, under the changing environmental conditions. Lake Nasser was originally a multispecies fishery during the first period of impoundment (1966-1975). At present, fish stocks are dominated by *Sarotherodon galilaeus* and *Oreochromis niloticus.* The remaining fish species have either declined to insignificant levels or almost in their way to disappear from the Lake. There has been no continuous information on the fish stocks in offshore and inshore waters of the Lake. Recently, Mekkawy (1998) carried out a study on fish stock assessment of Lake Nasser, with emphasis on those of *0. niloticus* and *S. galilaeus,* based on previous data collected by various investigators (Abdel-Azim 1974, Latif & Khallaf 1987, Yamaguchi *et al.* 1990, Vanden - Bossche & Bernacesk 1991, Adam 1994, Ahmad 1994, Mekkawy *et al,* 1994 & Mekkawy & Mohamed 1995).

IMPORTANT FISHING SITES AND KHORS

The presence of side extensions known as khors is an important feature of Lake Nasser. Fig. 2 shows the important fishing sites and khors of the Lake. The six major fishing areas of the Lake are shown in Fig. 149. The length of shoreline of khors is 969.9 km, the length of shores of eastern and western khors are 576.33 and 393.57 km respectively. The number of important khors is 85 of which 48 are located on the eastern side, and 37 on the western side (Fig. 2). The dimensions of some khors are shown in Table 101.

Table 101 **Dimensions of some khors of Lake Nasser***

Name of khor	Position in the Lake	Distance from the HD km	Length (km)		Area (km^2)		Perimeter (km)		Depth (m) at 160m level	Water volume (million m^3)	
			at 180 m level	at 160 m level	at 180 m level	at 160 m level	at 180 m level	at 160 m level		From 160-180 m level	From bottom to 160 m level
Kendy	East	0.5	4.0	3.2	2.5	1.4	10	7	30	0.039000	0.042000
Wadi Kurkur	West	11.0	25.72	4.5	101.2	8.4	284	29	20	1.096000	0.168000
Wadi Dihmit	East	35.0	20.50	6.0	56.8	6.3	226	11.5	20	0.631000	0.126000
Wadi Kalabsha	West	46.0	47.20	22.0	620.0	54.0	517	85	40	6.740000	2.160000
Rahma	East	48.0	23.58	21.0	95.2	42.4	232	42	40	1.376000	1.696000
Wadi Abyad	East	68.0	18.30	14.0	48.7	9.60	184	31	20	0.583000	0.192000
Wadi Mariya	East	70.0	17.42	11.0	80.7	58.5	184	46	20	1.392000	1.170000
Wadi Abesco	East	185.0	18.56	16.0	139.8	41.20	79	46	20	1.810000	0.824000
Wadi El-Allaqi	East	100.0	54.83	30.5	490.8	64.7	510	100	40	5.555000	2.588000
El-Meharraka	East	125.0	8.7	6.5	99.25	14.4	53	15	20	1.136500	0.288000
Shaturma	East	160.0	19.0	10.2	25.96	11.3	211	27	30	0.372600	0.339000
Korosko	East	177.0	22.56	10.7	83.6	23.4	253	34	30	1.070000	0.702000
El-Genena	East	239.0	13.54	7.0	48.2	15.80	103	20	10	0.640000	0.158000
Tushka (East)	East	245.0	15.2	9.4	66.9	28.7	117	25	20	0.956000	0.574000
Tushka (West)	West	245.0	33.35	24.1	366.8	49.10	127	89	20	4.159000	0.982000
Wadi Hamido	East	254.0	15.0	4.8	100.0	27.10	55	19	20	1.271000	0.542000
Wadi Or	East	285.0	19.23	6.3	52.4	11.3	110	19	20	0.637000	0.226000
Adindan	East	304.0	8.7	4.8	10.5	6.8	16	9	20	0.173000	0.136000
Sourah	West	312.0	21.05	15.0	122.4	24.40	60	42	20	1.468000	0.488000

***Source : Survey Department, High Dam Lake Development Authority, Aswan.**

According to the perimeter, the important khors are in the following order: Khor Kalabsha, Wadi El-Allaqi, Kurkur, Korosko, Khor El-Birba (El-Ramla), Rahma, Dihmit, Shaturma, Wadi Abyad, Mariya, Masmas, Tushka and Or which have perimeters more than 100 km at 180 m level. This factor seems to be important from the aspect of fish production as open water fishing has not yet been taken up. Surface area at this stage of fishery development is relatively less important (Latif 1974b).

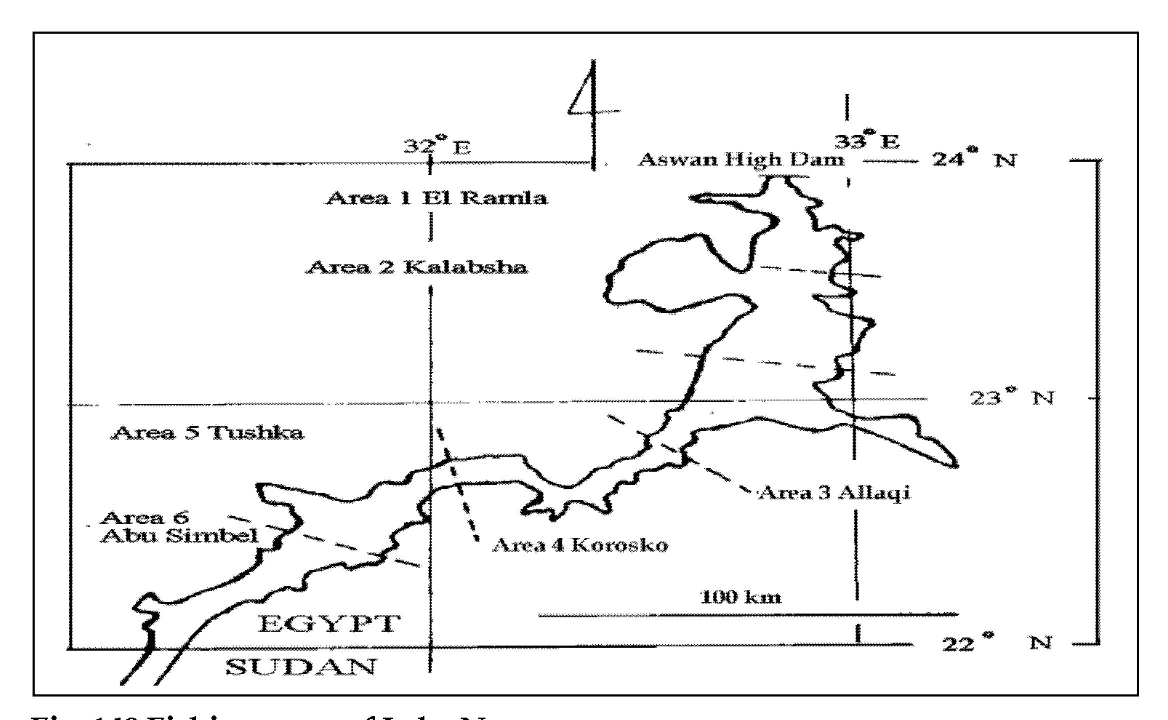


Fig. 149 Fishing areas of Lake Nasser.

FISH PRODUCTION

A list of commercial fishes from Lake Nasser is presented in Table 102. The pre-dominant marketable fresh fishes are *Sarotherodon galilaeus, Oreochromis niloticus, Lates niloticus, Labeo* spp., *Bagrus* spp. and *Synodontis* spp., while the salted fishes are mostly *Hydrocynus forskalii, Alestes* spp. and *Schilbe (Eutropius) niloticus* (Latif 1974a and b and 1977).

Fish are usually landed either fresh or salted. The amount of salted fish was considerable and formed from 44.73 to 56.72% with an average of 51.75% during the first period (1966-1968). During the second period (1969-1978), the percentage of salted fish decreased and ranged between 21.44 and 40.63% with an average of 32.72% (Tables 103 and 104). A sharp decline in the salted fish was noticed during the last period (1979-1996), since the percentage of salted fish in the landings ranged between 3.88 and 16.18% only with an average of 10.30% (Tables 103 and 104).

Table 102 **List of the commercial fishes of Lake Nasser.**

Family	Species	Local name	
Cichlidae	*Oreochromis niloticus*	Bolti Nili	بلطى نيلى
	Sarotherodon galilaeus	Bolti Galilae	بلطى جاليلى
Centropomidae	*Lates niloticus*	Samoos, Ishr-Bayad	ساموس - قشر بياض
Bagridae	*Bagrus bajad*	Bayad	بياض
	Bagrus docmak	Docmak	دقماق
Cyprinidae	*Labeo niloticus*	Lebeis abyad	لبيس أبيض
	Labeo coubie	Lebeis aswad	لبيس أسود
	Labeo horie	Lebeis aswad	لبيس أسود
	Barbus bynni	Benni	بنى
Clariidae	*Clarias anguillaris*	Karmout Zaflout	قرموط زفلوط
	Clarias gariepinus	Karmout Lazeer	قرموط لازير
	Heterobranchus bidorsalis	Karkour Hela	كركور حالا
	Heterobranchus longifilis	Karkour Asli	كركور أصلى
Characidae	*Hydrocynus forskalii*	Kalb-el-samak	كلب السمك
	Brycinus nurse	Sardina	سردينه
	Alestes dentex	Raya, Omaya	رايه
	Alestes baremoze	Raya, Omaya	رايه
Mormyridae	*Mormyrus kannume*	Boweza, Anooma	بويز - أنومه
	Mormyrus caschive	Boweza, Anooma	بويز - أنومه
Schilbeidae	*Schilbe (Eutropius) niloticus*	Schilba	شلبه
	Schilbe (Sehilbe) mystus	Schilba	شلبه
	Schilbe uranoscopus	Schilba-Arabi	شلبه عربى
Synodontidae	*Synodontis spp.*	Schall.	شال

Commercial fish species according to their feeding habits

The commercial fishes are classified by Latif *et al.* (1979), according to their feeding habits in the following groups:

1. Periphyton-plankton feeders including *Sarotherodon galilaeus* and *Oreochromis niloticus.*

2. Zooplankton-insect feeders represented by *Alestes* spp.

3. Omnivorous fish feeding mostly from the bottom and or between stones, including mainly *Barbus* sp., *Labeo* sp., synodontids, shilbeids and mormyrids.

4. Carnivorous fish including *Bagrus* spp., *Lates* sp., *Hydrocynus* spp., *Clarias* spp. and *Heterobranchus* spp.

Table 103 **Commercial fish landings from Lake Nasser (1966-1999) in relation to water level and number of fishing boats. [Data from: Statistical Department, Central Managment Fisheries Resources, Lake Nasser Development Authority, Aswan.**

Year	Total landings (ton)	Fish landings (ton)				Water level (m above sea level)			No. of fishing boats
		Fresh fish		Salted fish		Maximum	Minimum	Average	
		ton	%	ton	%				
1966	751	347	46.21	404	53.79	141.32	119.20	130.17	200
67	1415	782	55.27	633	44.73	151.08	133.48	142.28	350
68	2662	1152	43.28	1510	56.72	156.55	145.29	150.92	500
69	4670	2802	60.00	1868	40.00	161.29	150.80	156.05	599
1970	5676	3370	59.37	2306	40.63	164.88	153.81	159.35	816
71	6819	4316	63.29	2503	36.71	167.64	159.65	163.65	1039
72	8343	5303	63.56	3040	36.44	165.30	162.49	163.90	1135
73	10587	8027	75.82	2560	24.18	166.32	158.20	162.26	1440
74	12255	8030	56.52	4225	34.48	170.64	161.00	165.82	1540
75	14635	10384	70.95	4251	29.05	175.71	165.60	170.66	1630
76	15791	10929	69.21	4862	30.79	176.55	172.42	174.49	1680
77	18471	12279	6648	6192	33.52	177.21	171.69	174.45	1690
78	22725	17852	78.56	4873	21.44	177.49	172.44	174.97	1700
79	27021	22649	83.82	4372	16.18	175.95	173.03	174.49	1613
1980	30216	26344	87.19	3872	12.81	176.22	171.18	173.70	1570
81	34206	31295	91.49	2911	8.51	175.96	171.13	173.55	1500
82	28667	25979	90.62	2688	9.38	172.63	170.18	171.41	1450
83	31282	28885	92.34	2397	7.66	169.86	165.64	167.75	1388
84	24534	22069	89.95	2465	10.05	169.42	162.97	166.20	1385
85	26450	24975	94.42	1475	5.58	164.34	156.15	160.25	1382
86	16315	15.023	92.08	1292	7.92	163.61	156.14	160.38	1379
87	16815	15287	90.91	15.28	9.09	161.66	154.50	158.08	1379
88	15888	14579	91.76	1309	8.24	168.82	150.62	159.72	1244
89	15650	14031	89.65	1619	10.35	169.79	164.30	167.05	1175
1990	21882	20129	91.99	1753	8.01	169.50	163.72	166.61	1915
91	30838	29642	96.12	1196	3.88	169.35	162.23	165.79	1927
92	26219	24721	94.29	1498	5.71	170.75	163.84	167.30	1961
93	17931	16723	93.26	1208	6.74	174.32	167.24	170.78	1900
94	22074	20491	92.83	1583	7.17	177.28	169.51	173.40	2304
95	22058	19692	89.27	2366	10.73	176.93	172.32	174.62	2200
1996	20541	18160	88.41	2381	11.59	178.55	172.28	175.41	2200
97	20601	16644	80.79	3957	19.21	178.52	175.40	177.38	2200
98	19203	15013	78.18	4190	21.82	181.30	174.66	178.13	2200
1999	13983	9876	70.63	4107	29.37	181.60	175.66	178.92	2200

Table 104 **Percentage of fresh and salted fish landings from Lake Nasser during different periods (1966-1996).**

	Percentage of fresh fish landings		Percentage of salted fish landings	
	Range	Average	Range	Average
1966-1968	43.28-55.27	48.25	44.73-56.72	51.75
1969-1978	59.37-78.56	67.28	21.44-40.63	32.72
1979-1996	83.82-96.12	89.70	3.88-16.18	10.30

The percentages by weight of fishes with different feeding habits during the period from 1966 to 1996 are shown in Table 105. Also, the average percentage by weight of fishes with different feeding habits during three successive periods (1966-1972, 1973-1978, and 1979-1996) are shown in Table 106 and Fig. 150. From the aforementioned results it is obvious that the composition of fish landings is in favour of periphyton-plankton feeders. Thus, during the first period (1966-1972) the average percentage of the annual catch of periphyton-plankton feeders was 39.92%. This percentage increased gradually during the following periods, being 66.27 and 88.27% during the second (1973-1978) and third (1979-1996) periods (Table 106 Fig. 150). On the other hand, the average percentage of the annual catch of carnivorous and zooplankton-insect feeders was 42.04% during the first period (1966-1972), which decreased gradually to 32.96 and 10.76% during the second and third periods respectively. Furthermore, the average percentage of the annual catch of omnivorous fishes was 18.04% during the first period (1966-1972), followed by a sharp decrease to 0.77 and 0.97% during the second and third periods respectively (Table 106 and Fig. 150).

Evolution and trends of total fish catch

The total fish catch during 1966 -1999 is presented in Table 103 which shows a catch ranging from 751 to 34,206 ton with an average annual catch of 17.85 x 10^3 ton. The differences between the annual catch and the average annual yield (i.e. 17.85 x 10^3 ton) are presented in Fig. 151. It is obvious that a remarkable decrease from the average annual yield was recorded during the first period (1966-1976) (Fig. 151). On the other hand, the annual catch values were higher than the average annual yield during the second period (i.e. 1977-1985). It is worthy to mention that the drought period was from 1984 to 1988.

Table 105 **Percentage by weight of fishes with different feeding habits during the period from 1966 to 1996.**

Year	Percentage by weight of fishes (%)		
	Feeding habit		
	Periphyton-plankton feeders	**Carnivorous and zooplankton - insect feeders**	**Omnivorous feeders**
1966	37.06	45.07	17.87
7	33.33	44.80	21.87
8	28.73	43.07	28.20
9	42.30	37.30	20.40
1970	42.00	43.61	14.39
1	46.30	40.00	13.70
2	49.70	40.40	9.90
3	67.15	30.87	1.98
4	59.11	40.22	0.67
5	66.00	33.97	0.03
6	67.14	32.86	-
7	60.55	37.49	1.96
8	77.65	22.35	-
9	82.90	15.87	1.23
1980	84.16	14.60	1.24
1	89.25	9.49	1.26
2	82.72	16.21	1.07
3	90.43	8.93	0.64
4	93.21	5.90	0.89
5	93.22	6.14	0.64
6	90.34	7.29	2.37
7	86.37	11.00	2.63
8	86.21	11.51	2.28
9	83.12	14.88	2.00
1990	89.41	10.19	0.40
1	95.29	4.69	0.02
2	92.06	7.94	-
3	90.30	9.70	-
4	90.00	10.00	-
5	85.80	14.20	-
6	84.01	15.09	-

(-) not recorded

Table 106 **Average percentage by weight of fishes with different feeding habits during three successive periods.**

Period	Average percentage by weight of fishes (%)		
	Feeding habit		
	Periphyton-plankton feeders (1)	Carnivorous and zoo-plankton - insect feeders (2)	Omnivorous fishes (3)
1966-1972	39.92	42.04	18.04
1973-1978	66.27	32.96	0.77
1979-1996	88.27	10.76	0.97

(1) *Sarotherodon galilaeus* and *Oreochromis niloticus.*

(2) *Hydrocynus forskalii, Lates niloticus, Bagrus bajad, B. docmak, Brycinus nurse, A. dentex* and *A. baremoze.*

(3) *Labeo* spp., *Barbus* spp., synodontids, shilbeids and mormyrids

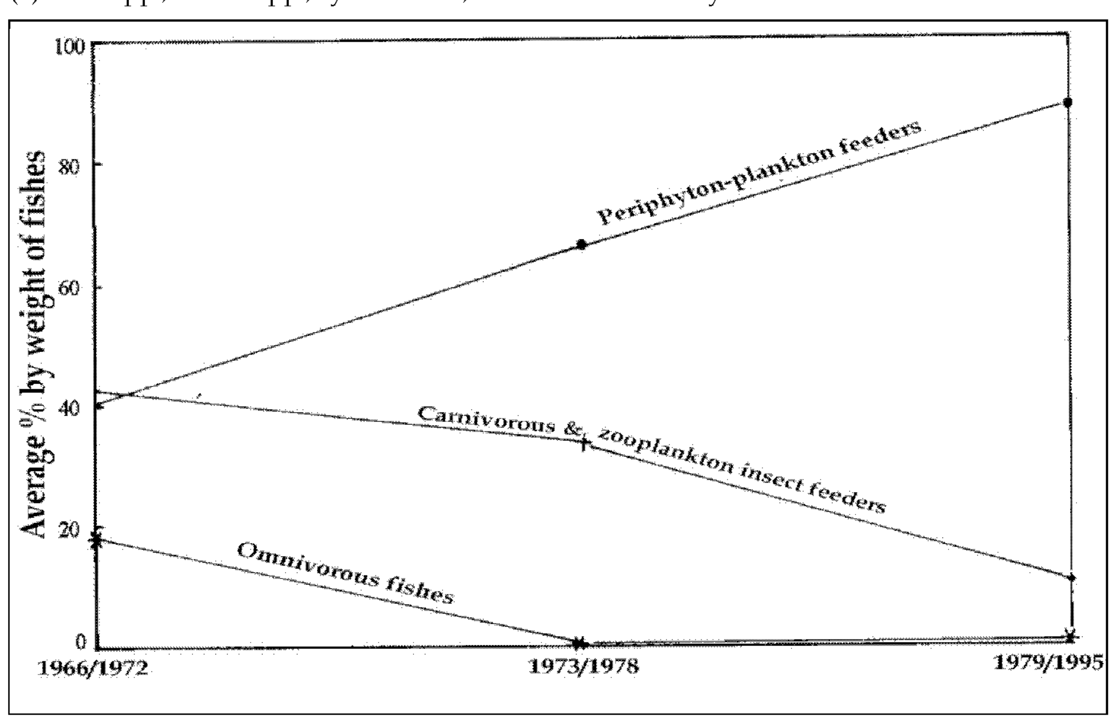


Fig. 150 **Average percentage by weight of fishes with different feeding habits during different periods.**

During the third period (1986 -1989) following the drought period a slight decrease from the average annual yield was observed followed by a sharp increase from the average value recorded during the last period (1990-1996) (Fig. 151).

Evolution and trends of different fish group catches

The evolution and historical trends of different fish group catches of Lake Nasser have been worked out by different investigators (Belal *et al.* 1992 Agaypi, 1993 a-

d and Mekkawy 1996). Agaypi (1993d) and Mekkawy (1996) studied in detail the correlations between the catch of the major fish group (*Tilapia* spp.) and those of the other fish groups in the lake.

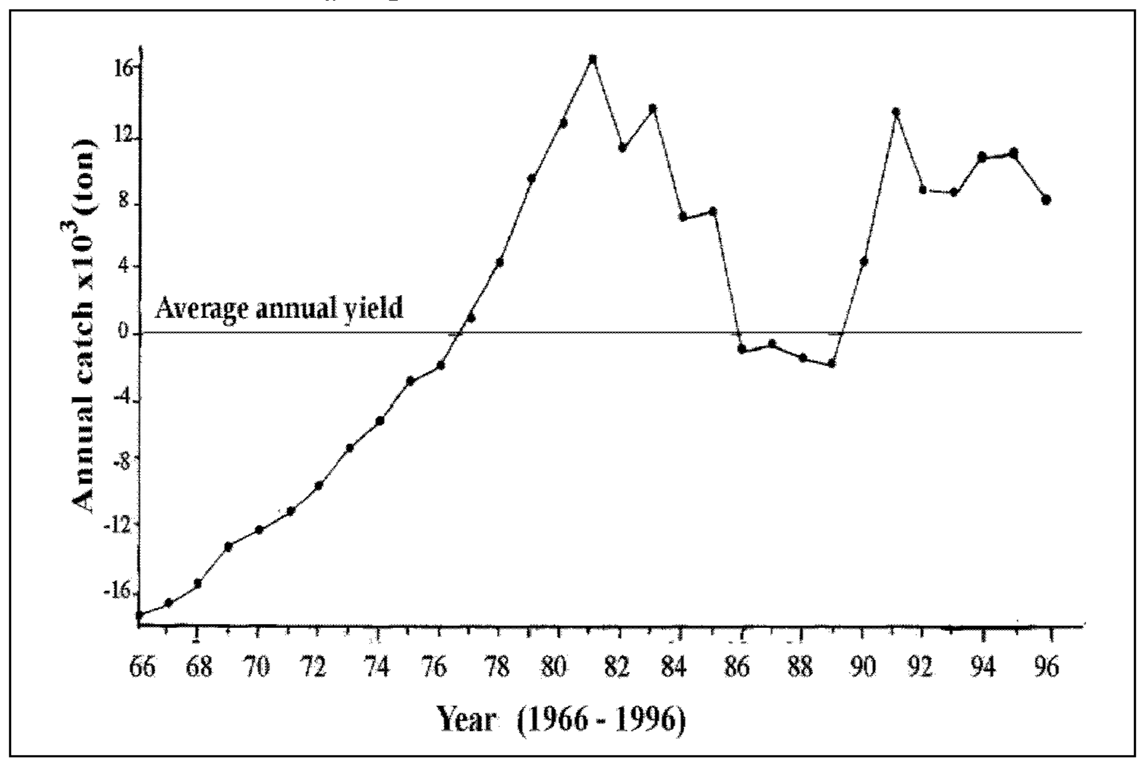
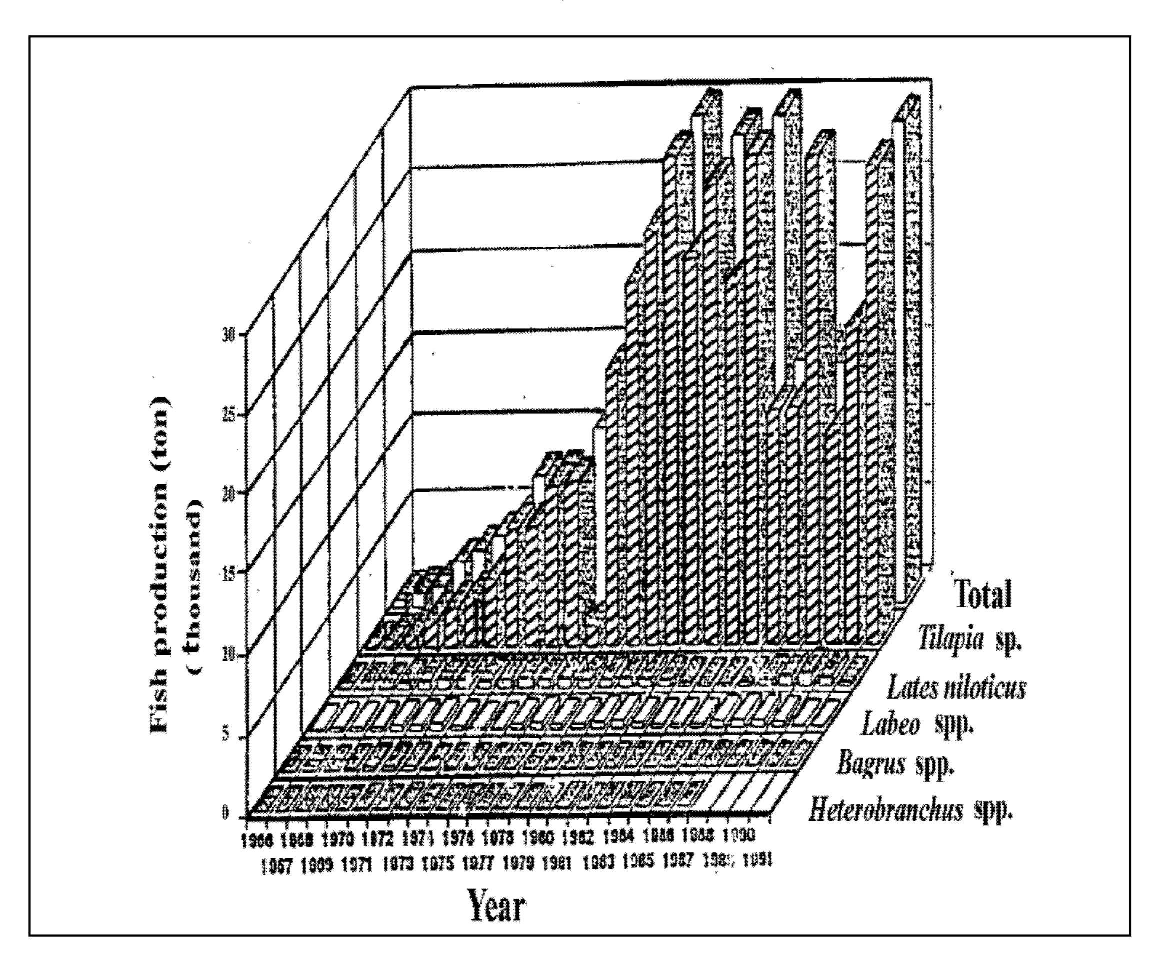


Fig. 151 **Difference between the annual fish production and the average annual yield (17.85 x 10^3).**

Lake Nasser is a huge reservoir, and as mentioned before, there are many kinds of fish species inhabiting the Lake. Among them tilapiine species mainly *Sarotherodon galilaeus* and *Oreochromis niloticus* (periphyton-plankton feeders) are the most dominant fish species (Figs. 152-154) particularly during the period 1979-1996, as their percentage by weight was high and ranged between 82.72 and 95.29% with an average of 88.27% (Tables 105 and 106). *Tilapia* species catches increased from 278 ton in 1966 to its maximum (i.e. 30,527 ton) in 1981. Afterwards, the tilapia catch decreased to about 13,000 ton in 1989, and this decrease was mainly due to the decline in the water level from 1984 to 1988 (the drought period) (Table 107 and Fig. 155), which led to a decrease in the length of the shoreline and its slope together with a decrease in the fishing grounds. As aforementioned, the length of the shoreline and its slope are important factors for the development of periphyton and littoral fauna, the main food of *Tilapia* species as well as the littoral areas provide tilapias with suitable breeding and nursery grounds. Furthermore, tilapia catch increased from 13,008 ton in 1989 to 19,563 and 29,383 ton in 1990 and 1991 respectively. At

the same time, there was a progressive decrease in the mean water level from 167.75 m in 1983 to 165.79 m in 1991. Tilapia catch decreased progressively from 29.383 ton in 1991 to 8606 ton in 1999. Simultaneously, the mean water level increased progressively during the same period (1991 - 1999) from 165.79 m in 1991 to 178.92 m in 1999. This indicates that there is a reverse relationship between the annual tilapia catch and the mean water level during the period 1991 - 1999. This may be attributed to that a large portion of tilapia catch is sold illegally in the black market, and hence not recorded in the official catches which do not represent the actual annual tilapia catch. Buhukaswan (1976) found a reverse relationship between annual water level fluctuation and commercial catch in Ubolratana Reservoir in Thailand. Also, Braimah (1995) observed a reverse relationship between the fish catch and the water level in Lake Volta, Ghana.



F*ig. 152* **Fresh fish production of Lake Nasser (1966-1991) (Belal *et al.,* 1992).**

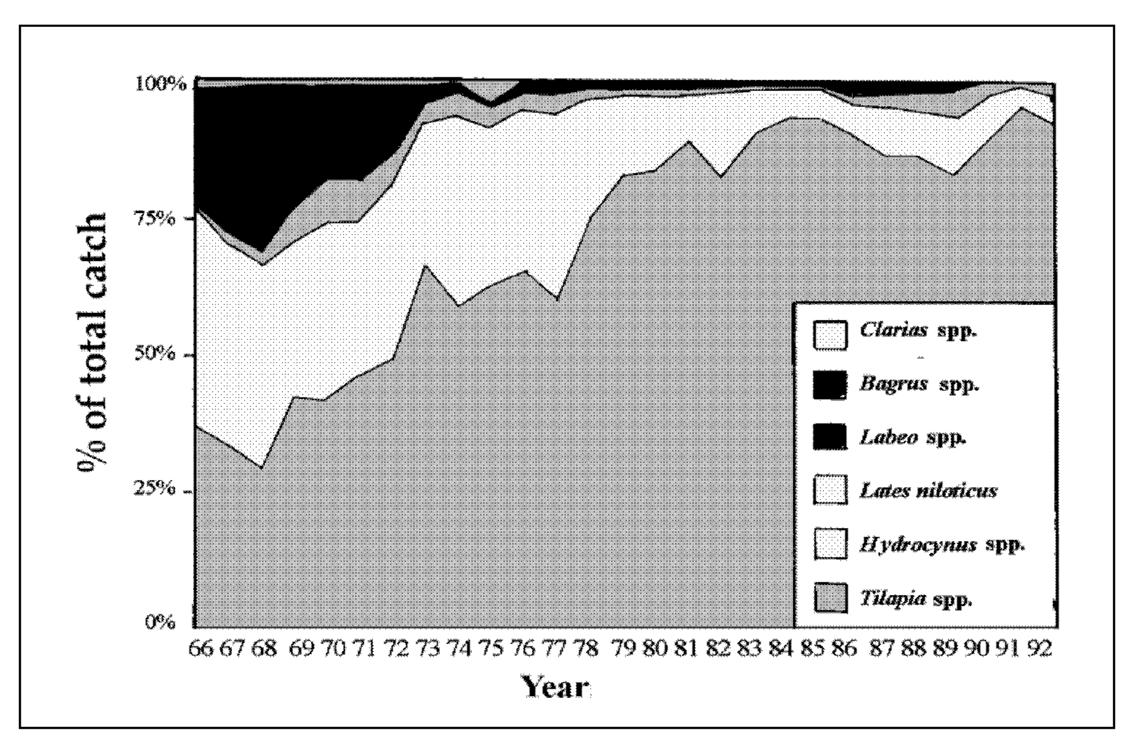


Fig. 153 **The evolution of different fish group catches in percentage of the total catch of Lake Nasser in 1966-1992 (Mekkawy 1996).**

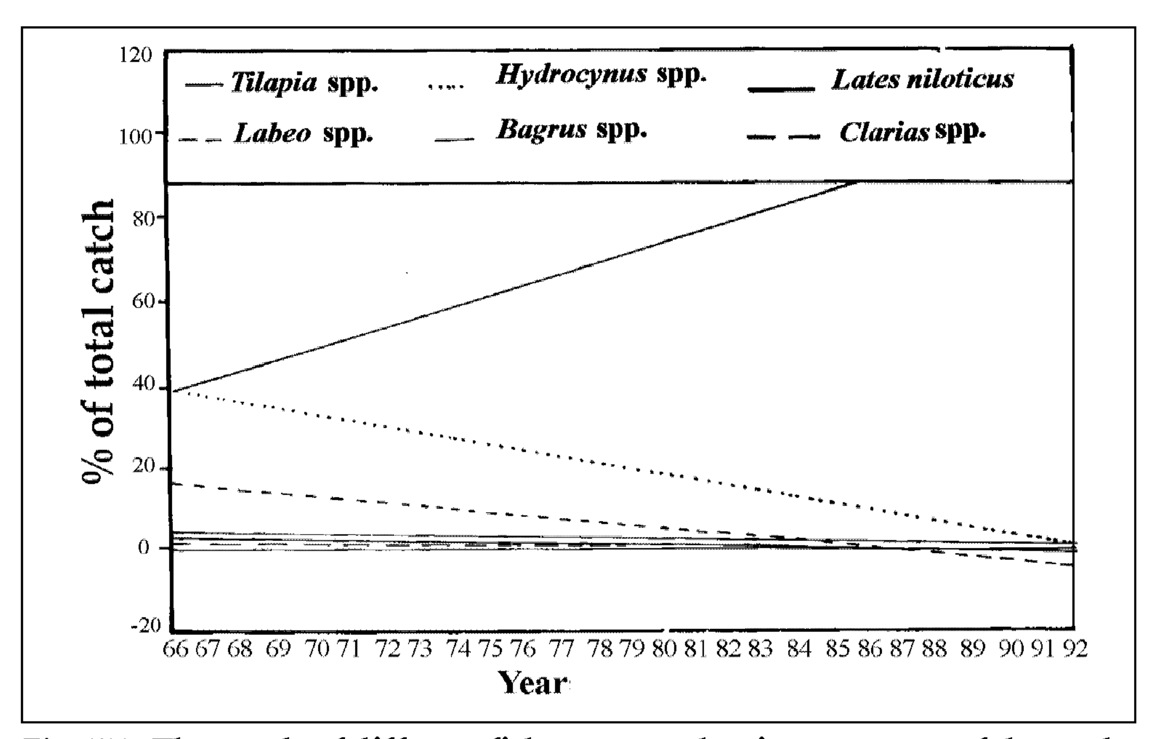


Fig. 154 **The trends of different fish group catches in percentage of the total catch of Lake Nasser in 1966-1992 (Mekkawy 1996).**

Table 107 **Annual catch (x10^3 ton) of the main fish species in Lake Nasser during 1996 - 1996. [Data from: Statistical Department , Central Management Fisheries Resources, Lake Nasser Development Authority Aswan].**

Species	Year															
	1966	**67**	**68**	**69**	**1970**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**1980**	**81**
Tilapia spp.	0.278	0.471	0.713	1.978	2.384	3.157	4.146	7.179	7.244	9.660	10.519	11.200	16.931	22.347	25.440	30.527
Hydrocynus forskalii	0.308	0.537	0.939	1.343	1.848	1.965	2.660	2.744	4.312	4.326	4.657	6.304	4.873	3.868	3.949	2.825
Lates niloticus	0.005	0.027	0.071	0.289	0.451	0.517	0.451	0.394	0.490	0.525	0.416	0.564	--	0.371	0.433	0.399
Labeo spp.	0.134	0.309	0.700	0.954	0.817	0.934	0.826	0.212	0.083	0.004	--	0.362	--	0.331	0.376	0.433
Bagrus spp.	0.025	0.069	0.059	0.112	0.176	0.245	0.258	0.162	0.127	0.121	0.075	0.066	--	0.045	0.031	0.021
Total	**0.750**	**1.413**	**2.482**	**4.676**	**5.676**	**6.818**	**8.341**	**10.691**	**12.256**	**14.636**	**15.667**	**18.496**	**21.804**	**26.957**	**30.229**	**34.205**
Mean water level (m)	130.17	142.28	150.92	156.05	159.35	163.65	163.90	162.26	165.82	170.66	174.49	174.45	174.97	174.49	173.70	173.55

	Year														
	1982	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**
Tilapia spp.	23.712	28.220	22.862	23.267	14.930	14.548	13.897	13.008	19.563	29.383	24.136	16.189	19.874	18.953	17.257
Hydrocynus forskalii	4.361	2.524	1.309	1.403	0.952	1.544	1.308	1.620	1.753	1.195	1.497	1.208	1.583	2.366	2.382
Lates niloticus	0.274	0.256	0.134	0.129	0.250	0.307	0.547	0.709	0.476	0.251	0.584	0.534	0.617	0.739	0.902
Labeo spp.	0.308	0.200	0.218	0.159	0.393	0.443	0.367	0.312	0.089	0.007	--	--	--	--	--
Bagrus spp.	0.011	0.006	0.004	0.002	0.002	0.001	0.001	0.000	0.000	0.000	--	--	--	--	--
Total	**28.666**	**31.206**	**24.527**	**24.969**	**16.527**	**16.843**	**16.120**	**15.649**	**21.881**	**30.836**	**26.217**	**17931**	**22074**	**22058**	**20541**
Mean water level (m)	171.41	167.75	166.20	160.25	160.38	158.08	159.72	167.05	166.61	165.79	167.30	170.78	173.40	174.62	175.41

The annual catch of *Hydrocynus forskalii* increased gradually from 308 ton in 1966 to 6,304 ton in 1977, followed by a sharp decrease to 952 ton in 1986 (Table 107 and Fig. 155). From 1987 to 1994, the catch was around 1,500 ton annually, ranging between 4.06 and 12.45 % with an average of 8.61% of the total annual catch (Table 107 and Fig. 155). During 1995 and 1996, the catch increased and reached 2,366 and 2,382 ton respectively (Table 107).

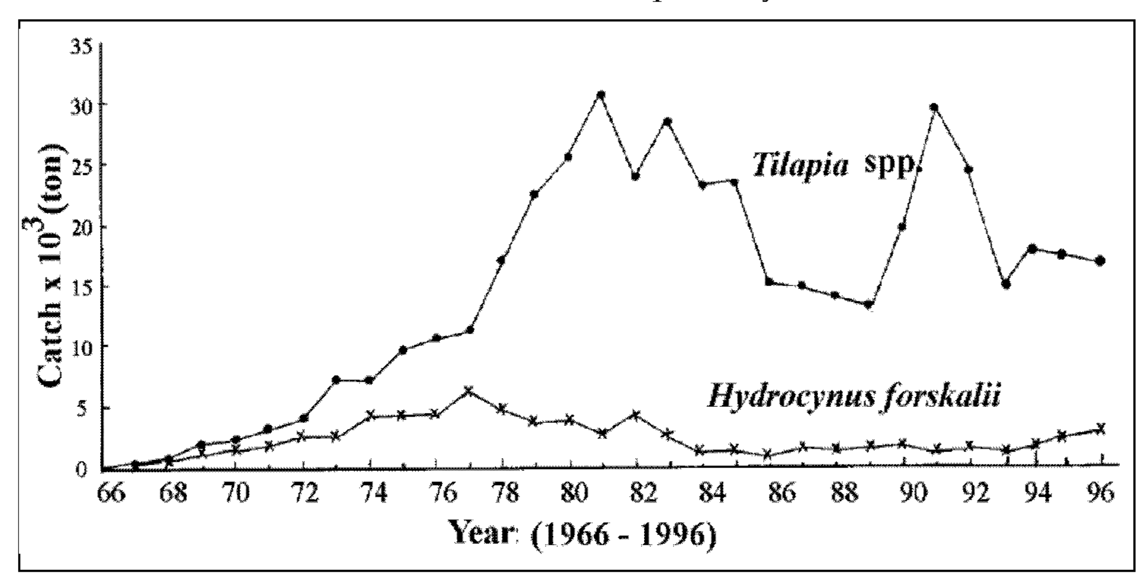


***Fig. 155* Annual catch of the main fish species: *Tilapia* species and *Hydrocynus forskalii* from Lake Nasser (1966-1996).**

Lates niloticus catch increased from only five ton in 1966 to 564 ton in 1977. Then, the catch fluctuated greatly from no landings in 1978 to 902 ton (4.39 % of the total annual fish catch) in 1996 (Table 107 and Fig. 156), and 400.4 ton (4.05% of the annual fresh fish catch) in 1999.

Labeo species catch increased rapidly from 134 ton in 1966 to attain its maximum (i.e. 954 ton) in 1969.Then the catch fluctuated greatly between no landings in 1976, 1978 and 1992-1996, and 934 ton (13.7% of the total annual fish catch) in 1971 (Table 107 and Fig. 156). During 1985-1991, the catch fluctuated between 443 ton during 1987 and 7 ton in 1991. It is obvious that no landings were recorded between 1992 and 1996. In 1999 a remarkable increase to 869.5 ton (about 8.8% of the annual fresh fish production) was recorded.

Bagrus species catch increased from 25 ton in 1966 to 258 ton (3.09 of the total annual fish catch) in 1972, and thereafter the catch decreased and no fish were landed from 1989 to 1996 (Table 107 and Fig. 156).

As aforementioned, there are many kinds of fish species inhabiting Lake Nasser, and among them *Tilapia* species have been the dominant species. Therefore, the production of *Tilapia* species may affect the production of other

fish species. Agaypi (1993d) examined the relationship between *Tilapia* species catch and other fishes catch (Figs. 157-160), and his results are summerized as follows:

1. The relation between *Tilapia* species catch and that of *Hydrocynus forskalii* looks like a roughly dome shaped curve (Fig. 157). *H. forskalii* catch increased gradually from 1966 to 1977 and the catch of *Tilapia* species reached 10,000 ton in 1977. After 1979 *Tilapia* species catch reached 20,000 ton, then *H. forskalii* catch decreased. Therefore, when *Tilapia* species production reached more than 15,000 ton, then the production of *H. forskalii* may be affected by *Tilapia* species yield. Agaypi (1993d) examined the correlation by comparing two periods, one from 1966 to 1977 and the other from 1979 to 1992. The value of correlation coefficient in the former was 0.964 and *H. forskalii* catch increased without any obstacle. While in the latter it was without any relation and this suggested that increasing of *Tilapia* species production might affect the yield of *H. forskalii* and the critical catch of *Tilapia* species might be more than 15,000 ton.

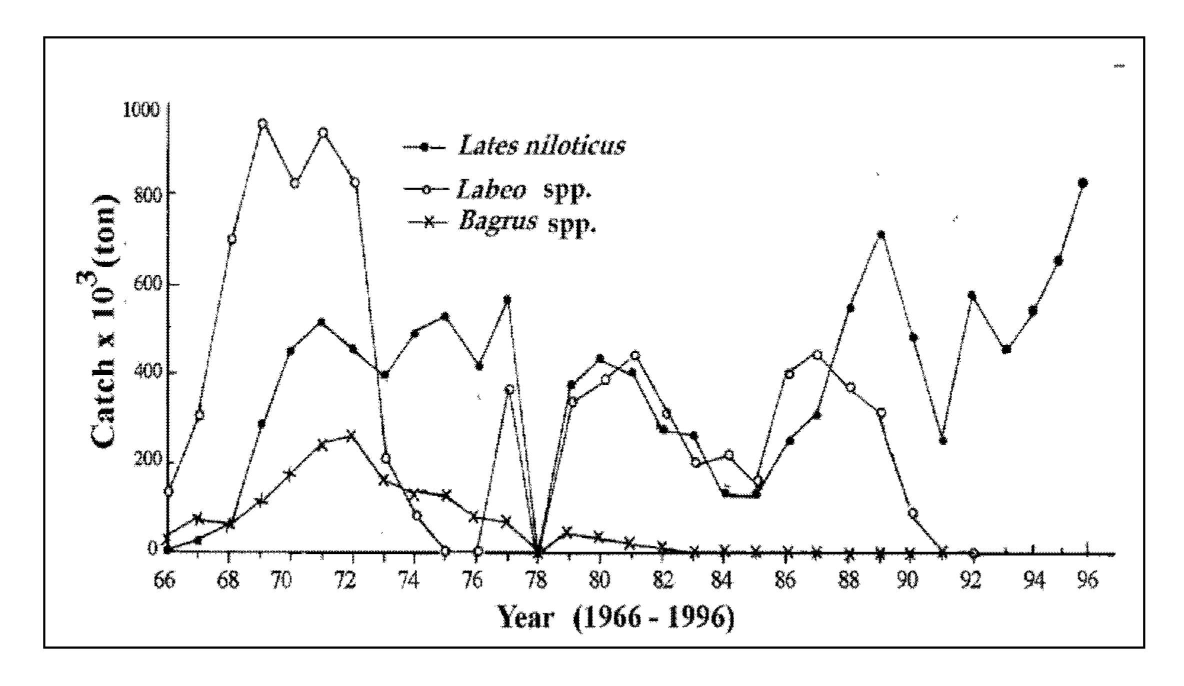


***Fig. 156* Annual catch of *Lates niloticus*, *Labeo* species and *Bagrus* species from Lake Nasser (1966-1996).**

2. The relation between *Tilapia* species catch and that of *Lates niloticus* catch (Fig. 158) shows that the catch of the latter species increased gradually until 1974, while *Tilapia* species catch reached 7,000 ton during this year. After 1975 *Tilapia* species production increased parallel with a decrease of *Lates niloticus* catch as a general tendency. Therefore, *L. niloticus* catch may be affected by the amount of *Tilapia* species catch of more than 15,000 ton. Agaypi (1993d) calculated the correlation coefficient, comparing the two periods, one from 1966 to 1974 and the other from 1975 to 1992. The value of correlation coefficient in the former

was 0.745 and *L. niloticus* catch increased without any obstacle. While, in the latter period the value of correlation coefficient was without any relation and this suggested that a catch more than 15,000 ton of *Tilapia* species might affect the catch of *Lates niloticus.*

3. The relation between *Tilapia* species catch and that of *Labeo* species showed a sharp increase until 1969, but after 1973 the catch decreased rapidly (Fig. 159). The catch of *Tilapia* species in 1973 reached 7,000 ton. It seems that *Labeo* species catch may be affected by the catch of *Tilapia* species when it reaches more than 10,000 ton. Agaypi (1993d) found that the correlation coefficient was 0.753 from 1966 to 1972, while from 1973 to 1992 there was no relation. This suggests that when *Tilapia* species catch attains more than 10,000 ton, it may affect the catch *of Labeo* species.

4. The relation between *Tilapia* species catch and that of *Bagrus* species (Fig. 160) shows that the catch of *Bagrus* species increased gradually until 1972, after 1973, it showed a gradual decrease corresponding to the increase of *Tilapia* species catch. In 1972 the catch of *Tilapia* species was 5,000 ton. It seems that *Bagrus* species catch may be affected by the catch of *Tilapia* species, when it is more than 5,000 ton. *Bagrus* species catch decreased after 1972 with a simultaneous increase of *Tilapia* species catch. The correlation coefficient from 1966 to 1972 was 0.973 and from 1973 to 1992 was 0.664 (Agaypi 1993d). This suggests that more than 5,000 ton of *Tilapia* species catch might affect the catch of *Bagrus* species leading to its decrease.

It is concluded from Agaypi's results that:

a. The annual catch of *H. forskalii* and *Lates. niloticus* may be affected by *Tilapia* species catch when it is more than 15,000 ton thus leading to a decrease in the annual production of the former two species.

b. The annual catch of *Labeo* species and *Bagrus* species shows a decrease, when *Tilapia* species catch is more than 10,000 and 5,000 ton respectively.

The statistical analysis of the commercial catch of Lake Nasser fisheries showed significant relationships between the catch of the predominant group, the tilapiines and the catch of others (Table 108 - Mekkawy 1998). The negative high correlations between tilapiine catch and those of *Hydrocynus, Labeo* and *Bagrus* were due to the pre-drought period (1966 - 1983). These correlations remained high for *Hydrocynus* and relatively high for *Labeo* in the post-drought period (1989 - 1992). *Lates niloticus* and *Clarias* spp. exhibited low negative correlations due to the post-drought period for the first species and due to the whole period for the second. Mekkawy (1998) summarized the aforementioned patterns of relationships by the cluster analysis which discriminated the commercial catch into two main clusters: tilapiine cluster and the cluster of other fish groups (Fig. 161).

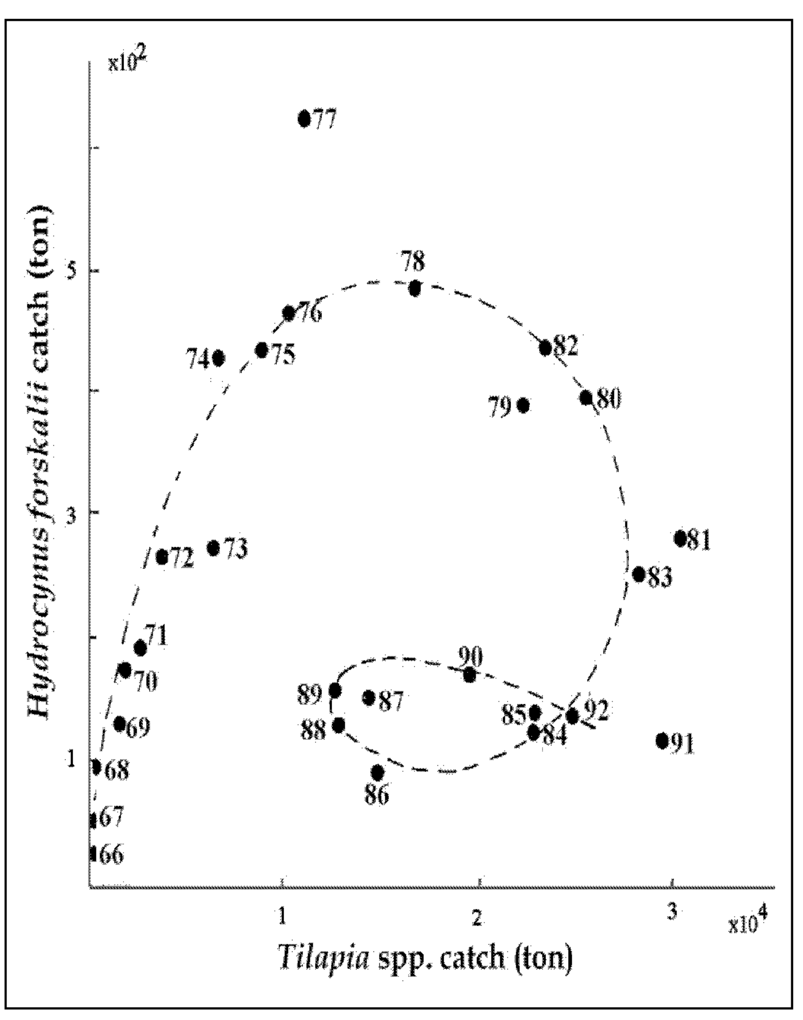


Fig. 157 **Relation between *Tilapia* species catch and that of *Hydrocynus forskalii* (Agaypi 1993d).**

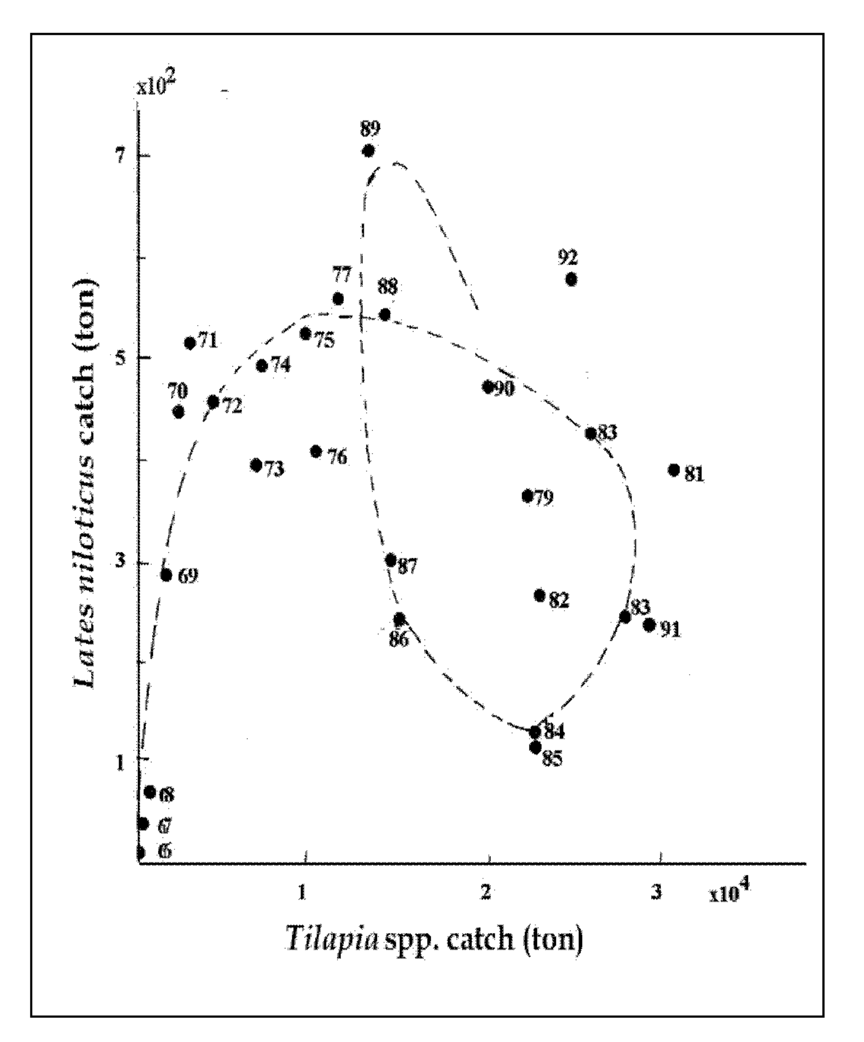


Fig. 158 **Relation between *Tilapia* species catch and that of *Lates niloticus* (Agaypi 1993d).**

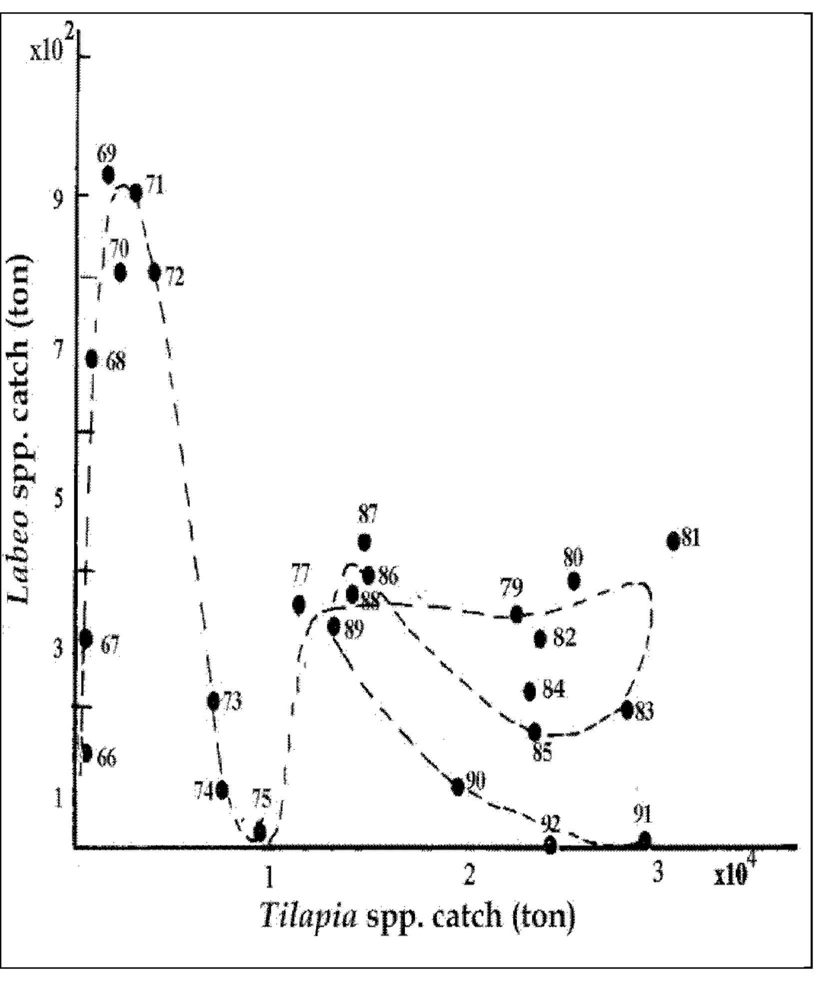


Fig. 159 **Relation between *Tilapia* species catch and that of *Labeo* spp. (Agaypi 1993d).**

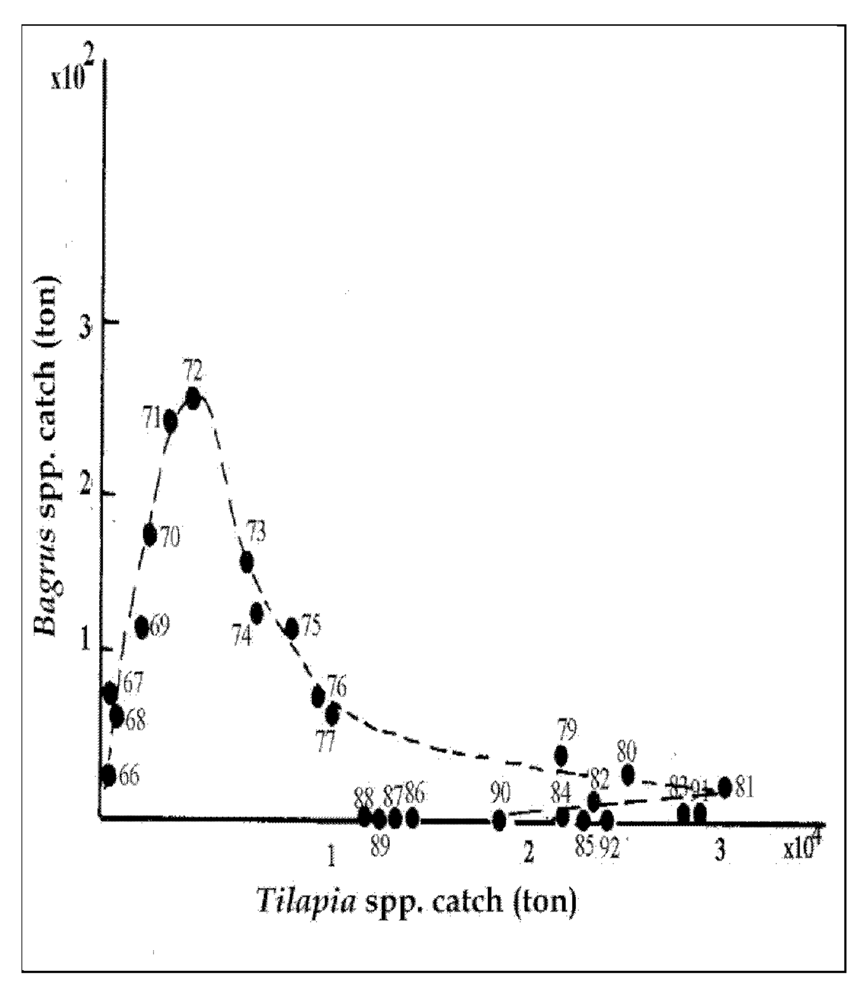


Fig. 160 **Relation between *Tilapia* species catch and that of *Bagrus* spp. (Agaypi 1993d).**

Table 108 **Significant relationships between *Tilapia* spp. catch and the catch of other fish groups of Lake Nasser, in terms of their regression coefficients (b), Y-intercepts (a) and correlation coefficients (R) (Mekkawy 1998).**

Fish species	R	a	b
	1966 - 1992		
Hydrocynus sp.	-0.946**	57.86	0.543
Lates niloticus	-0.560**	6.48	0.053
Labeo spp.	-0.865**	28.01	-0.319
Bagrus spp.	-0.900**	5.20	-0.059
Clarias spp.	-0.563**	2.45	-0.025
	1966 – 1980		
Hydrocynus sp.	-0.857**	50.41	- 0.385
Labeo spp.	-0.899**	35.51	- 0.478
Bagrus spp.	-0.858**	5.86	- 0.073
	1981- 1992		
Hydrocynus sp.	-0.906**	68.12	-0.677
Lates niloticus	-0.583**	17.65	-0.179
Labeo spp.	- 0.617**	13.89	-0.143

** highly significant at 0.01

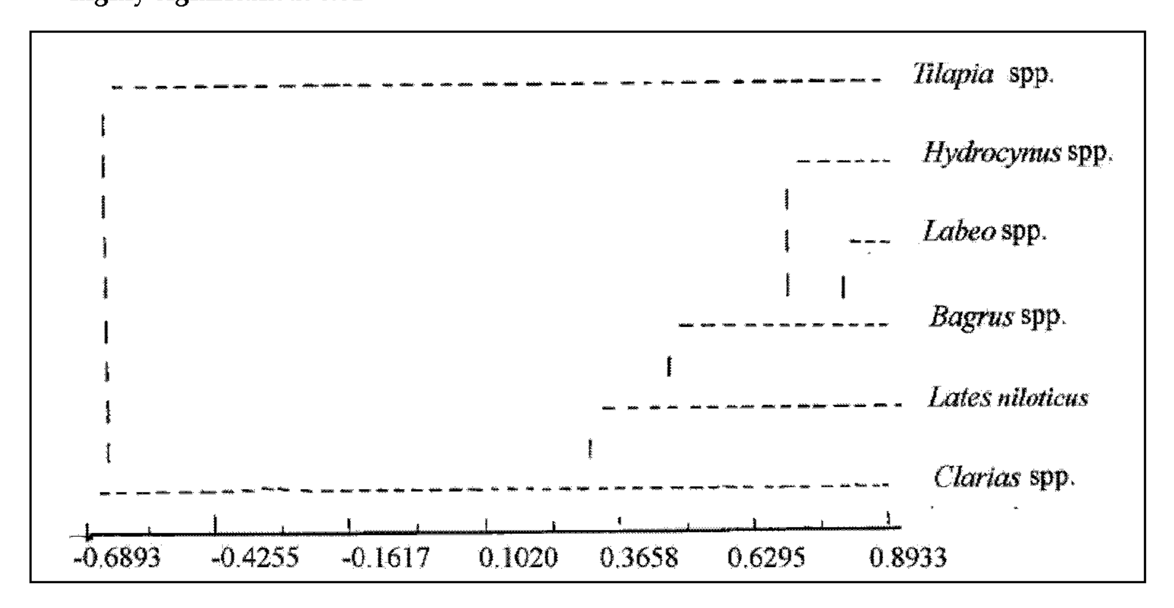


Fig. 161 **Clustering (weighted pair group method) of Lake Nasser (1966-1992) fish species based on the intercorrelation matrix of their annual catch (% weight of the total catch) (based on data by Agaypi 1993d and Ahmed 1994) (Mekkawy 1998).**

The rates of change, towards increase or decrease, of commercial fish groups are given in Table 109. Tilapiine group showed a positive annual rate of change over 1966 - 1992, whereas other species showed negative rates. The rate of change of the total catch also exhibited yearly variations (Table 110 - Mekkawy 1998).

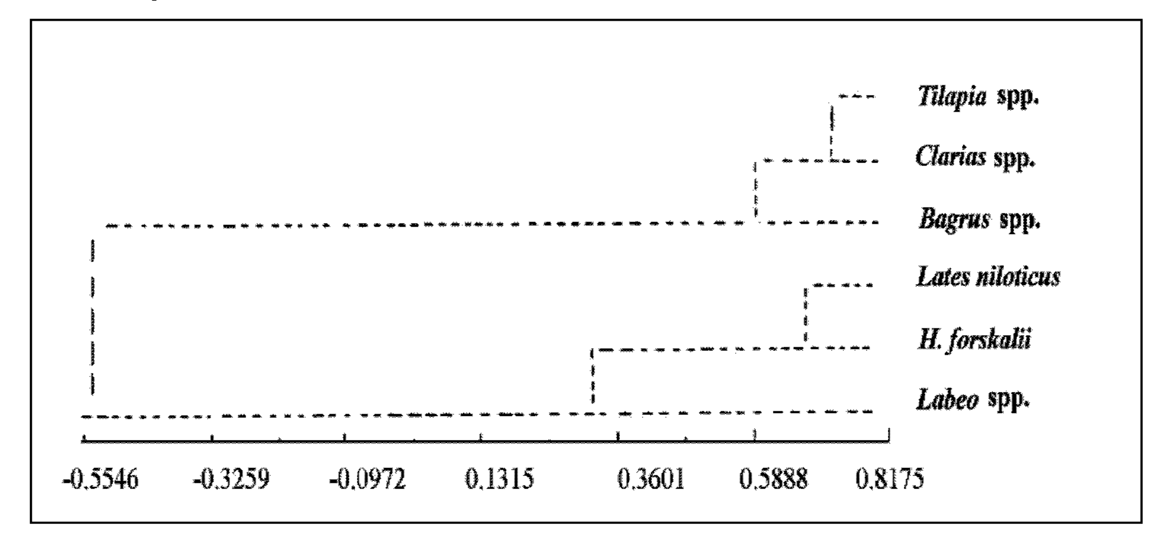


Fig. 162 **Clustering (weighted pair group method) of Lake Nasser (1983-1991) fish species based on the intercorrelation matrix of their annual catch (% weight of the total catch) (based on data by Agaypi 1993d and Ahmad, 1994). (Mekkawy 1996).**

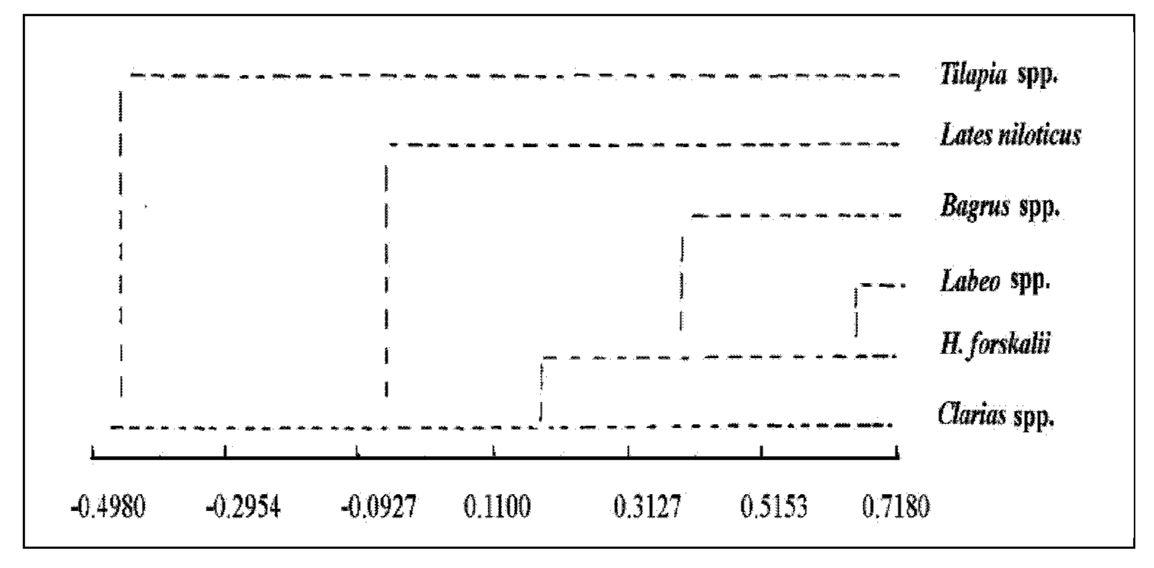


Fig. 163 **Clustering (weighted pair group method) of Lake Nasser (1983) fish species based on the intercorrelation matrix of their annual catch (% weight of the total catch) (based on data by Agaypi 1993d). (Mekkawy 1996).**

Table 109 **The significant trend analysis parameters of different fish groups catch of Lake Nasser through 1966-1992 period (Mekkawy 1998).**

Fish species	General mean	R	a	b	Rate of change (%)
***Tilapia* spp.**	70.4419	0.925	35.1651	2.5197	3.58
***Hydrocynus* sp.**	19.6120	- 0.920	39.7959	- 1.4381	-7.33
Lates niloticus	2.7411	- 0.434	4.3101	-0.1121	-4.09
***Labeo* spp.**	5.533	-0.744	16.0041	- 0.7479	- 13.52
***Bagrus* spp.**	1.0078	- 0.834	3.1089	- 0.1501	- 14.89
***Clarias* spp.**	0.6644	- 0.584	1.6659	- 0.0715	- 10.76

Refer to Table 108 for abbreviations.

Table 110 **Trend analysis parameters of the total catch of different khors of fish groups of Lake Nasser through August and December 1988-1992 (Mekkawy 1998).**

Month / year	Mean	R[1]	a[1]	b[1]	Rate of change (%)
Aug.1988	21635.23	0.362**	122274.96	234.007	1.08**
Dec. 1988	12981.53	-0.170	15513.65	- 63.303	-0.49
Aug.1989	13344.43	- 0.395**	19803.02	- 161.463	- 1.21**
Dec. 1989	14395.87	-0.149	17027.62	- 65.794	-0.46
Aug. 1990	29339.01	- 0.031	30211.84	-21.821	-0.07
Dec. 1990	29853.54	0.117	26426.31	85.681	0.29
Aug.1991	42902.36	0.260**	33706.51	229.896	0.54**
Dec. 1991	44901.62	0.128	34864.01	250.940	0.56
Aug. 1992	29691.27	0.483**	11845.50	466.144	1.57**
Dec. 1992	27204.03	0.375**	17356.94	246.177	0.90**

1, Refer to Table 108 for abbreviations. **** highly significant at 0.01.**

Fish species composition of experimental catches

Table 111 and Fig. 164 show the fish species composition of High Dam Lake. Floating and sinking gill nets were used in experimental fishing in the reservoir during October 1978 and July 1979 (Latif *et al.* 1979). The results are summarized in the following:

1. In Lake Nasser, *Sarotherodon galilaeus, Lates niloticus, Hydrocynus forskalii* and *Mormyrus* spp. were more in the northern third than elsewhere in the Lake. *Oreochromis niloticus,* on the contrary, is much more frequent in the middle third. *Alestes baremoze* and A. *dentex* are mainly concentrated in the southern third where cyprinids are more frequent.

2. In Lake Nubia, *Tilapia* spp. are less frequent than in Lake Nasser. High percentage of *Sarotherodon galilaeus* prevailed in the southern third of Lake Nubia. *Alestes baremoze* and *A. dentex* appeared only in the northern third of Lake Nubia but to a much less extent than in the southern part of Lake Nasser. *Schilbe uranoscopus* is an important component (6-7%) in the middle and southern thirds. Cyprinids form numerically more than 50% of the catch in these two sections, thus exhibiting much higher values than in Lake Nasser.

3. *Hydrocynus* spp. show an increasing pattern from the southern third of Lake Nubia northwards till the northern section of Lake Nasser. *Barbus bynni* is concentrated in the middle third of the whole reservoir.

EFFECT OF DIFFERENT WATER LEVELS AND EFFORT ON FISH PRODUCTION

The number of fishing boats operating in Lake Nasser during the period from 1966 to 1999 is presented in Table 103 and Fig. 166. It started with 200 boats in 1966 and gradually increased to 1700 in 1978, while from 1979 to 1989, it gradually decreased from 1613 to 1175. The number of fishing boats was stable (about 1900) during 1990 to 1993, increased thereafter to about 2300 in 1994 and 2200 in 1995, 1996 and 1999.

It is beleived that there is a relationship between the total annual fish production of the Lake and the water level, which shows remarkable fluctuations from year to year. The highest percentage of fish (83-95.3%) is composed of *Tilapia* spp. (viz., *S. galilaeus* and *0. niloticus*) which inhabit shallow inshore waters, the area of which is profoundly affected by the water level. Hence consideration of the water level and total fish production since the filling of the Lake till now is important. Table 103 and Fig. 165 show the maximum, minimum and mean water levels, while Figs. 167 and 168 show the fluctuations in the total annual catch in relation to water level. From these data the following is observed:

Table 111 **Percentage number of different fish species among catch by floating and sinking gill-nets in different sections of high Dam Reservoir (Latif *et al.* 1979).**

Species	**Lake Nasser**			**Lake Nubia**		
	Northern	**Middle**	**Southern**	**Northern**	**Middle**	**Southern**
Oreochromis niloticus	0.22	33.6	--	0.53	0.56	--
Sarotherodon galilaeus	18.50	8.16	0.87	7.27	2.38	29.7
Lates niloticus	18.60	13.10	3.54	13.17	11.95	4.5
***Hydrocynus* spp.**	54.13	34.87	27.00	9.75	7.31	1.2
***Bagrus* spp.**	0.44	--	--	4.69	1.3	1.4
***Alestes* spp.**	1.94	4.15	23.1	1.06	--	1.4
Schilbe uranoscopus	--	--	--	--	5.85	6.83
Schilbe (Schilbe) mystus	--	--	--	--	0.79	--
Eutropius niloticus	--	--	0.79	3.52	4.07	6.0
***Synodontis* spp.**	1.29	2.6	3.13	24.5	9.63	25.4
***Mormyrus* spp.**	6.68	3.37	0.14	2.99	1.36	1.67
Labeo niloticus	--	--	1.23	23.74	49.00	17.7
Labeo coubie	--	--	0.39	33.15	2.38	1.4
Labeo horie	--	--	0.53	1.59	--	0.7
Barbus bynni	--	0.15	4.67	4.69	2.82	2.16

Oreochromis niloticus
Sarotherodon galilaeus
Lates niloticus
Hydrocynus spp.
Bagrus spp.
Alestes spp.
Schilbe uranoscopus
Schilbe mystus
Eutropius niloticus
Synodontis spp.
Mormyrus spp.
Labeo niloticus
Labeo coubie
Labeo horie
Barbus bynni

North Middle South North Middle South
Lake Nasser Lake Nubia

Fig. 164 **Diagram of species composition of different sectors of high Dam Reservoir based on experimental fishing. (Latif *et al.* 1979).**

1. From 1966 to 1976, the total catch increased and reached about 16,000 ton in 1976 with the increase of water level and number of fishing boats.

2. From 1976 to 1981, the total catch increased from about 16,000 to 34,000 ton. At that period, the mean water level attained was kept at about 174 m and the fishing effort was constant (1600 fishing boats). Thus, the water level was relatively high and so, very suitable for tilapia reproduction during this period. Mohamed & Adam (1995) pointed out that during the period from 1976 to 1982, the water level in Lake Nasser was about 174 m, and the total catch reached 34,000 ton in 1981, while in 1982 the catch decreased to 28,700 ton (Figs. 167 and 168). The latter authors considered the catch of 34,000 ton as overfishing at that low water level, and they estimated the tentative sustainable yield as the mean catch of 1980 and 1982, or (30,200 + 28,700) /2 = 29,450 ton at the low water level of about 172 m.

3. From 1982 to 1988, - including the drought period - the total catch decreased from 29,000 to 16,000 ton (i.e. about 50%) and there was a decrease in the mean water level from 171 m to 160 m (Figs. 167 and 168).

4. During 1989 to 1992, the low water level was nearly 164 m and the total catch reached 30,800 ton in 1991, but in 1992, the catch decreased to 26.000 ton (Figs. 167 and 168). Mohamed & Adam (1995) estimated the tentative sustainable yield as the mean value of the catches in 1990 and 1992 or (21,900 + 26,200)/2 = 24,050 ton, at the low water level of about 164 m.

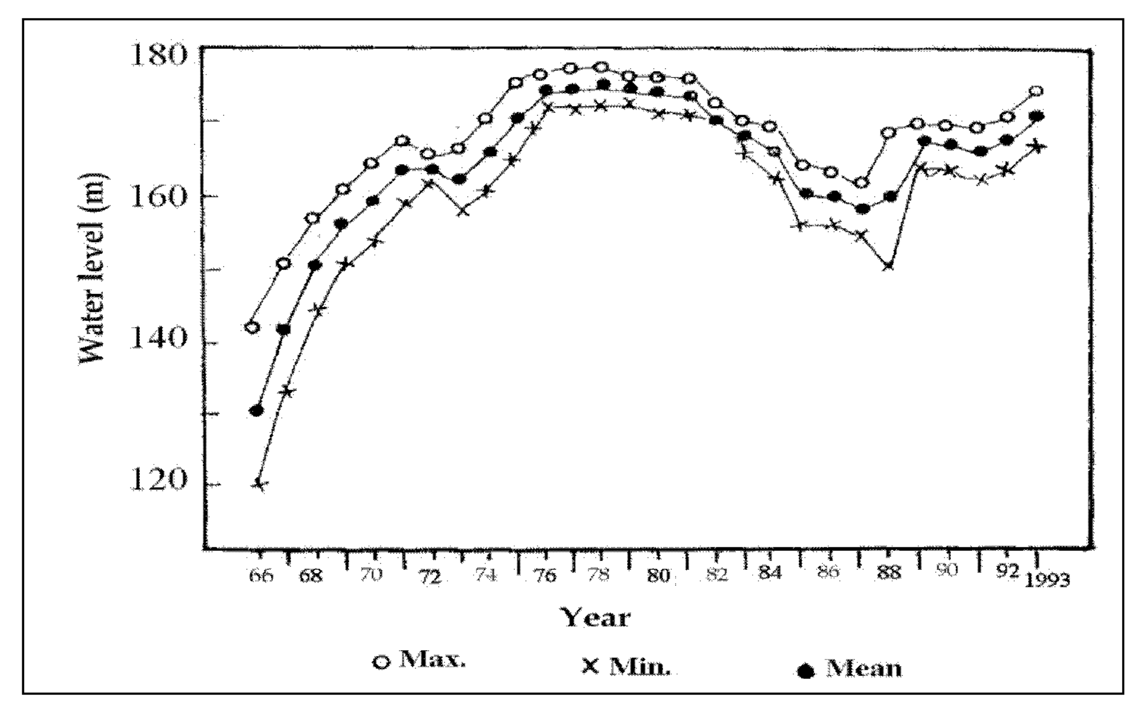


Fig. 165 **Maximum, minimum and mean water level of Lake Nasser (1966-1993) (Agaypi 1995b).**

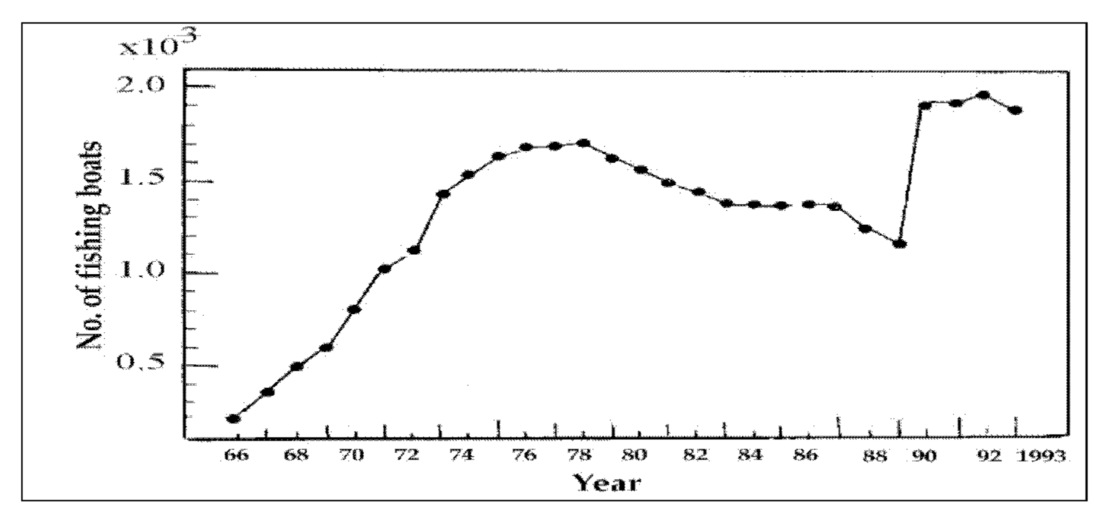


Fig. 166 **Number of fishing boats in Lake Nasser (1966-1993) (Agaypi 1995 b).**

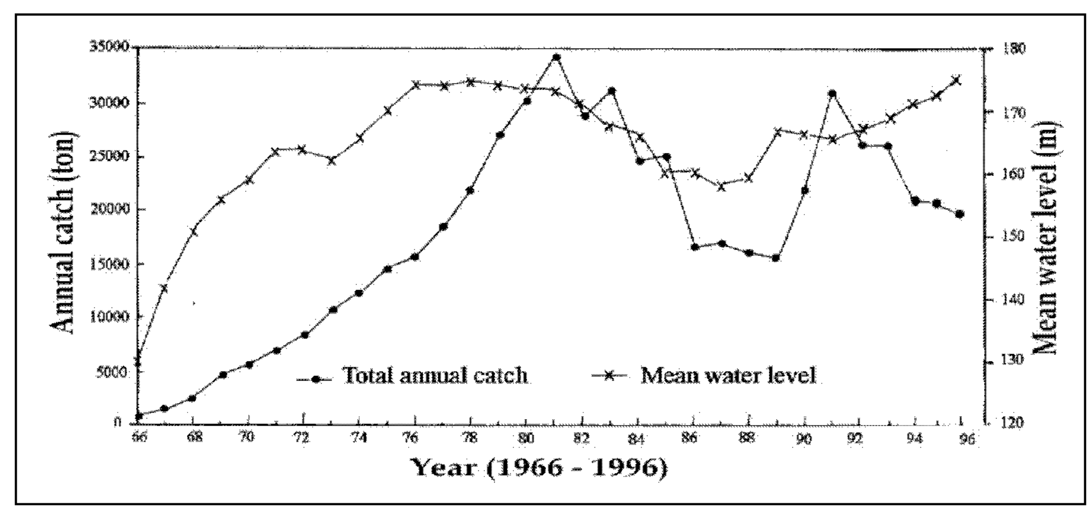


Fig. 167 **Fluctuation of the total annual catch in relation to the mean water level.**

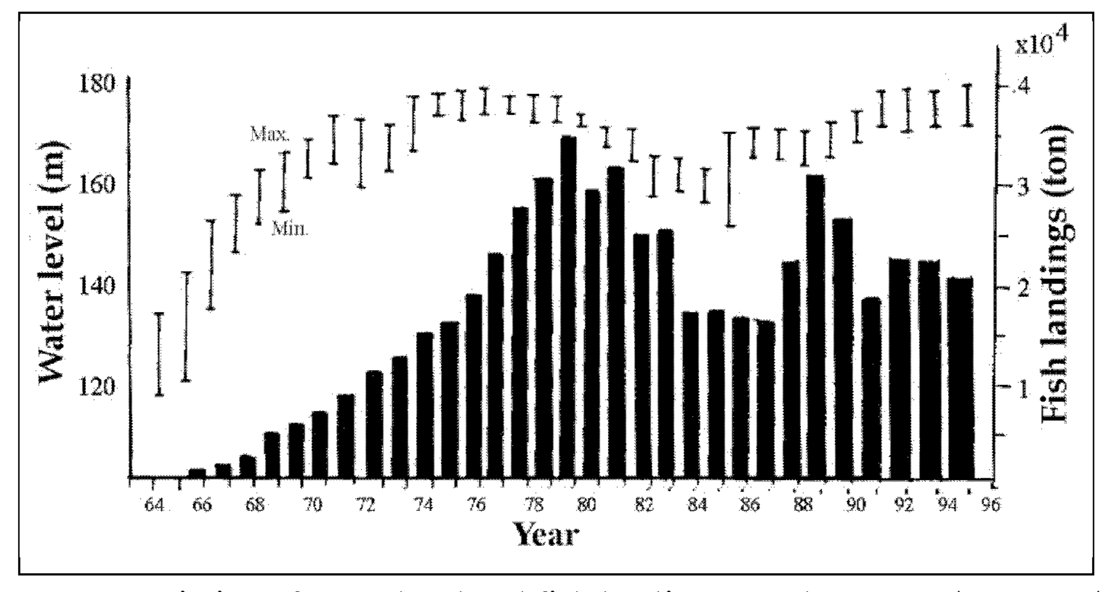


Fig. 168 **Variation of water level and fish landings at Lake Nasser (1964-1996) (Agaypi 1995 b).**

As a matter of fact, fish production in Lake Nasser is affected by many factors including prohibiting of fishing from 15th March to 15th May, which started from 1990. Agaypi (1995b) attributed the decrease in the total catch from 34,000 ton in 1981 to 29,000 ton in 1982 to overfishing, because the mean water level was high during previous years (about 174 m), showing favourable environmental conditions for fish production. Similarly, the total catch decreased from 30,838 ton in 1991 to 26,219 ton in 1992 and 17,931 ton in 1993, followed by an increase to 22,074, 22,058, 20,541 and 20,601 ton in 1994,1995, 1996 and 1997 respectively. Then, the total catch decreased to 19,203 and 13,983 ton in 1998 and 1999 respectively.

The catch is considered a dependent variable, while both water level and effort, represented by the number of fishing boats per year and number of fishermen per year, are independent variables. Using the multiple linear regression, Mekkawy (1998) presented the relations as follows :

Total catch (Multiple R = 0.94885, P < 0.0001) = - 189029.7664** - 411.3143 WL1 + 762.0031 WL2 + 777.9169 WL3* - 42.6486 WL4 + 34.6586 WL5 - 12.2834 WL6 + 11.3704 boat** + 0.5496 fisherman

Tilapiine catch (Multiple R = 0.944, P < 0.0001) = - 186212.43** - 292.1281 WL1 + 638.0132 WL2 + 806.2936 WL3* - 152.6959 WL4 + 240.1809 WL5 - 68.0935 WL6 + 11.1222 Boat** + 0.8626 fisherman.

***Hydrocynus* catch** (Multiple R = 0.891, P < 0.003) = - 13879.41 + 170.0945 WL1* + 63.9416 WL2 - 81.6443 WL3 - 26.2004 WL4 - 69.4056 WL5 + 60.9031 WL6 - 0.8624 Boat - 0.2870 fisherman.

***Lates* catch** (Multiple R = 0.853, P < 0.01) = 2553.66 + 11.7921 WL1 - 9.5386 WL2- 9.3175 WL3 + 7.4938 WL4 - 30.6562 WL5* + 17.6134 WL6* + 0.12056 Boat - 0.0320 fisherman

***Bagrus* catch** (Multiple R = 0.949, P < 0.0001) = 1056.41** + 0.4917 WL1 - 0.8188 WL2 - 0.5188 WL3 + 0.0868 WL4 + 6.2542 WL5 - 10.1625 WL6** - 0.0221 Boat - 0.0040 fisherman

N.B. (1) * or ** means that the parameter is significant at 0.05 or highly significant at 0.01.

(2) WL1 - WL6 = previous water levels from 1 to 6 years.

Table 112 shows the relationships between the commercial catch of fish groups of 1972 - 1992 and both efforts (boat / year and fisherman / year) and combination of flood histories in terms of maximum water levels (WL) of the six years preceding the catch - year (Mekkawy 1998). Using the correlation coefficients, the latter author concluded from that table the following:

1- Significant correlations between tilapiine catch and WL2 to WL6, insignificant correlation with effort.

2- Significant correlations between *Hydrocynus* spp. catch and WL1, WL2 and effort (only fisherman / year).

3- Significant correlation between *Lates* sp. catch and WL5, insignificant correlation with effort.

4- Significant correlation between *Labeo* spp. catch and effort (only boat / year), insignificant correlations with water levels.

5- Significant correlation between *Bagrus* spp. catch and WL4 to WL6, insignificant correlation with effort.

6- Insignificant correlation between *Clarias* spp. catch and water levels and effort.

7- Significant correlations between total catch and WL2 to WL6 and insignificant correlations with effort; a case similar to that of tilapiine catch .

Table 112 **Simple correlation coefficients between fish species catch of Lake Nasser and water levels of the six preceding years and efforts (boats and fishermen (Mekkawy, 1998).**

	Correlation **coefficients**							
	WL1	**WL2**	**WL3**	**WL4**	**WL5**	**WL6**	**Boats**	**Fishermen**
***Tilapia* spp.**	0.34	0.58*	0.67*	0.62*	0.61*	0.63*	0.45	0.38
***Hydrocynus* spp.**	0.69**	0.51*	0.25	0.07	-0.09	-0.23	-0.36	-0.69**
Lates niloticus	0.05	-0.36	-0.47	-0.47	-0.56*	-0.42	0.18	-0.17
***Labeo* spp.**	0.05	-0.00	-0.01	-0.02	-0.00	-0.13	-0.55*	-0.41
***Bagrus* spp.**	-0.03	-0.18	-0.35	-0.53*	-0.68**	-0.87**	-0.48	-0.49
***Clarias* spp.**	0.13	0.03	-0.07	0.02	-0.08	-0.18	-0.02	-0.23
Total	**0.44**	**0.68****	**0.74****	**0.65****	**0.59***	**0.59***	**0.39**	**0.27**

*** Significant at 0.05, ** highly significant at 0.01. WL1-WL6 = previous water levels from one to six years.**

The multiple linear model, represented by these equations, treated simultaneously the most important factors : fishermen, boats and water levels, that control Lake Nasser catch.

Mekkawy (1998) mentioned that the total catch standardized by effort (CPUE) for 1972 - 1992 varied with variation of water levels (WL1 - WL6). The CPUE-WL relationships were described by the following equations (*, ** significant at 0.05 and 0.01 respectively).

Catch/boat	= 54.85 + 0.399 WL1,	r =0.490*
Catch /fisherman	=39.71 + 0.259 WL1,	r= 0.535**
Catch / boat	= - 94.42 + 0.632 WL2	r = 0.794**
Catch/fisherman	= - 49.06 + 0.310 WL2	r= 0.667**
Catch / boat	= - 99.24 + 0.662 WL 3	r = 0.876**
Catch / fisherman	= - 45.18 + 0.288 WL3	r = 0.652**
Catch/boat	= - 73.23 + 0.511 WL 4	r= 0.752**
Catch / fisherman	= - 33.56 + 0.220 WL 4	r = 0.555**
Catch / boat	= - 49.05 + 0.369 WL 5	r = 0.632**
Catch / fisherman	- = -21.65 + 0.151 WL 5	r = 0.441*
Catch / boat	= - 30.06 + 258 WL6	r = 0.544**
Catch / fisherman	= - 8.61 + 0.073 WL6	r = 0.265

The correlation coefficients of CPUE-WL relationships were significant, but relatively low except for catch / fisherman-WL

The picture obtained by Mekkawy (1998) using the multiple linear regression, makes it possible to predict the allowable catch considering the water level and effort.

Williams (1972) pointed out that the relation between annual water level fluctuation and catch per unit effort (CPUE) presents a predictive hypothesis, which has an important value in the management of fisheries. The latter author recorded a positive correlation between water level and the catch per unit effort in Mweru Lake in Zambia, and he referred this positive correlation to the effect of water level fluctuations on the spawning grounds of some fish species as *Tilapia macrochir*, which has certain limited depths for spawning.

A different picture is observed in Lake Nasser particularly during 1991 – 1999. One can notice a negative correlation between water level and tilapiine catch, which represents about 90% of the total fish catch. Thus, the mean water level increased progressively from 165.79 m in 1991 to 178.92 m in 1999; while tilapiine catch sharply decreased from 29,383 ton in 1991 to 8606 ton in 1999. This is mainly attributed to that, a large portion of the catch is sold illegally in the black market at high prices, and hence not recorded in the official catches, which thus do not represent the true annual tilapiine catch from the Lake.

The increase in the catch of commercial fishes may be reversely related to the increase in water level, taking into consideration that this increase is not correlated with the growth of plankton. Fig. 169 shows the relationship between annual water level fluctuation and commercial catch in Ubolratana Reservoir in Thailand (Buhukaswan, 1976). It is obvious that the catch fluctuates monthly. It increases during the dry season, when the water level decreases, while the catch decreases during the period of high water level. The fishermen can easily catch

fish during the dry season, when the water level is low and the fish concentrates in smaller areas (Buhukaswan, 1976). Varikol (1980) pointed out that the catch effort increases generally during the period when fishermen are free from culturing rice. Also, Braimah (1995) recorded a reverse relation between the catch and water level in Volta Lake in Ghana (Fig. 170). The latter author mentioned that tilapia catch was low, when the water level was high and vice versa. Furthermore tilapias are rarely found during water floods.

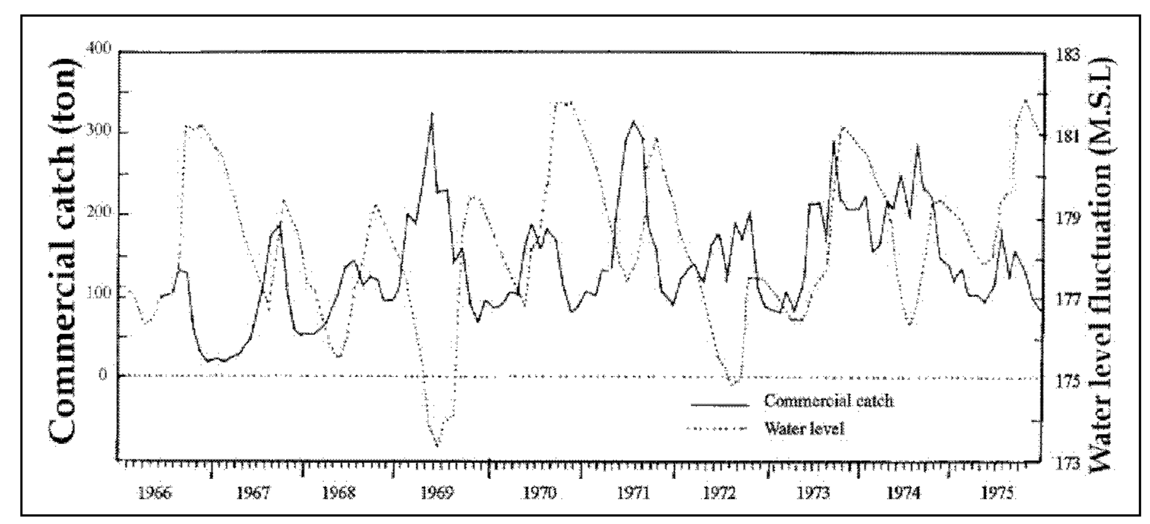


Fig. 169 **The relationship between annual water level fluctuation and commercial catch in the Ubolratana Reservoir, Khon Kaen, Thailand, July 1966 - December 1975 (Buhukaswan 1976).**

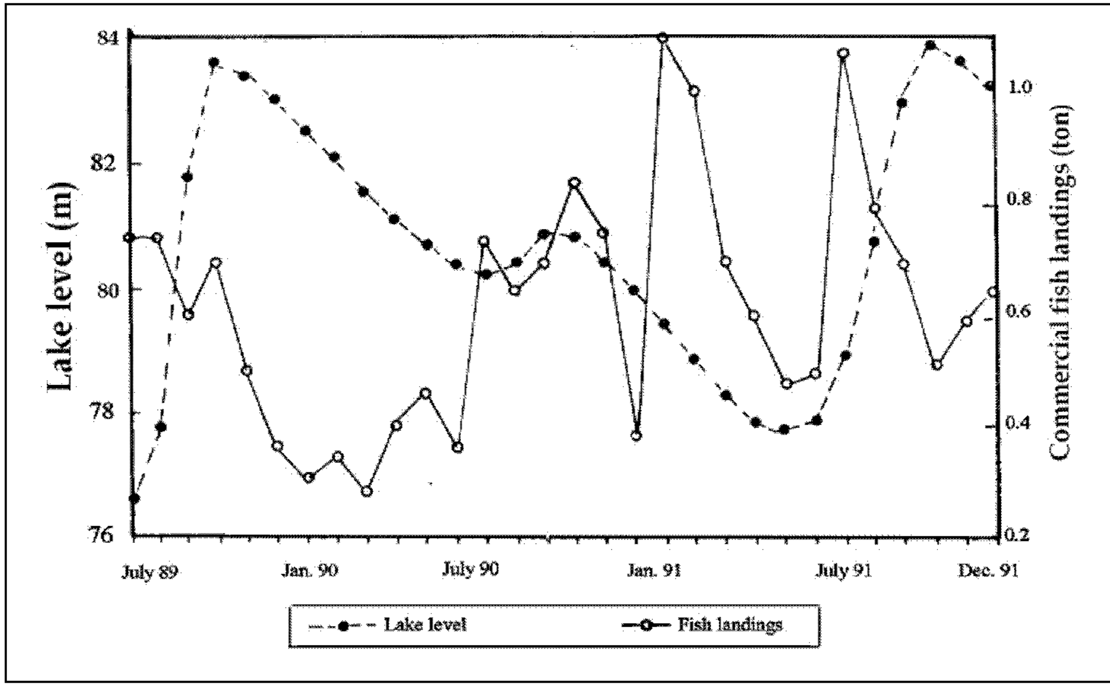


Fig. 170 **Water level and commercial catch of Volta Lake, Ghana in July 1989-December 1991 (Braimah 1995).**

EFFECT OF CHANGEABLE SHORELINE LENGTH ON FISH PRODUCTION

Yamaguchi *et al* (1996) used the following cubic equation for measuring the relationship between water level (H) and shoreline length (L).

$$L = LO + a\,(H-Ho) + b\,(H-Ho)^2 + c\,(H-Ho)^3 + e \quad \ldots\ldots\ldots\ldots (1)$$

where : a, b and c are constants, e is an error, and Ho and Lo are water level and shoreline length before High Dam construction . The constants a , b and c were obtained by the least square method. After calculation, the latter authors obtained the following equation:

$$L = 625 + 177.8\,(H - 112) - 5.054\,(H - 112)^2 + 0.0587\,(H - 112)^3 \ldots\ldots (2)$$

The mean water level in Lake Nasser, during the period 1966-1996 was calculated, and then the calculated mean length of shoreline, during the same period, was obtained by using equation (2) (Table 113).

Relation between total fish production and calculated length of shoreline of Lake Nasser

The mean length of shoreline (km) of Lake Nasser during 1966 -1996 is calculated, as shown in Table 113, using the mean water level (m) in different years applying equation (2).

It is obvious that the total fish production is affected (3 years afterwards) with the increase or decrease of the shoreline length of Lake Nasser (Table 113 and Fig. 171). Thus, there was a progressive increase in the calculated mean length of the shoreline from 2539 km in 1966 to 6438 km in 1978, and accordingly there was a successive increase in the total fish production from 4,670 in 1969 to 34,206 ton in 1981 (Table 113 and Fig. 171). So, it may be said that the total fish production increases (3 years afterwards) with the increase of shoreline length of the Lake. It is worth mentioning that there is a progressive increase in the shoreline length of Lake Nasser from 4702 km in 1991 to 7482 km in 1999 (Table 113), as a result of the continuous increase in he mean water level from 165.79 m in 1991 to 178.92 m in 1999 (Table 113). Accordingly, it is expected that the total fish catch, particularly tilapiines, should increase greatly during 1991 - 1999. However, a reverse picture is observed. Thus, tilapiine catch decreased sharply from 29,383 ton in 1991 to only 8606 ton in 1999. This observation is mainly attributed to that a high percentage of the catch is sold in the black market illegally at high prices. Hence, it is obvious that the official catches - which is taken in consideration in the present study - do not represent the true annual fish catch.

RELATIONSHIP BETWEEN CATCH AND GONAD INDEX

Monthly variations of gonad index of *O. niloticus* and *S. galilaeus* are shown in Table 114. For both tilapiine species, two major peaks were observed (Figs. 172 and 173). The monthly catch of both fish species exhibited two or three major peaks. However, the catch peaks do not coincide with those of

gonad index (Figs. 172 and 173).

Table 113 **Relation between total fish production and calculated length of the shoreline of Lake Nasser during 1966-1999.**

Year	Mean Water Level (m)	Calculated * length of shoreline (mean, km)	Total fish** production (ton) (Actual)
1966	130.17	2539	751
7	142.28	3005	1415
8	150.92	3350	2662
9	156.05	3668	4670
1970	159.35	3944	5676
1	163.65	4414	6819
2	163.90	4445	8343
3	162.26	4247	10587
4	165.82	4706	12255
5	170.66	5512	14635
6	174.49	6324	15791
7	174.45	6315	18471
8	174.97	6438	22725
9	174.49	6324	27021
1980	173.70	6143	30216
1	173.55	6109	34206
2	171.41	5659	28667
3	167.75	5000	31282
4	166.20	4761	24534
5	160.25	4032	26450
6	160.38	4045	16315
7	158.08	3830	16815
8	159.72	3979	15888
9	167.05	4890	15650
1990	166.61	4822	21882
1	165.79	4702	30838
2	167.30	4929	26219
3	170.78	5535	17931
4	173.40	6076	22074
5	174.62	6355	22058
6	175.41	6544	20541
7	177.38	7051	20601
8	178.13	7257	19203
9	178.92	7482	13983

*** Mean length of the shoreline of Lake Nasser is calculated using the equation:**

[$L = 625 + 177.8 (H - 112) - 5.054 (H - 112)^2 + 0.0587 (H - 112)^3$ .... Yamaguchi *et al.* (1996)]
(where, L = length of shoreline, H = water level).

****Total fish production is affected (at 3 year after) with the increase or decrease of calculated shoreline length.**

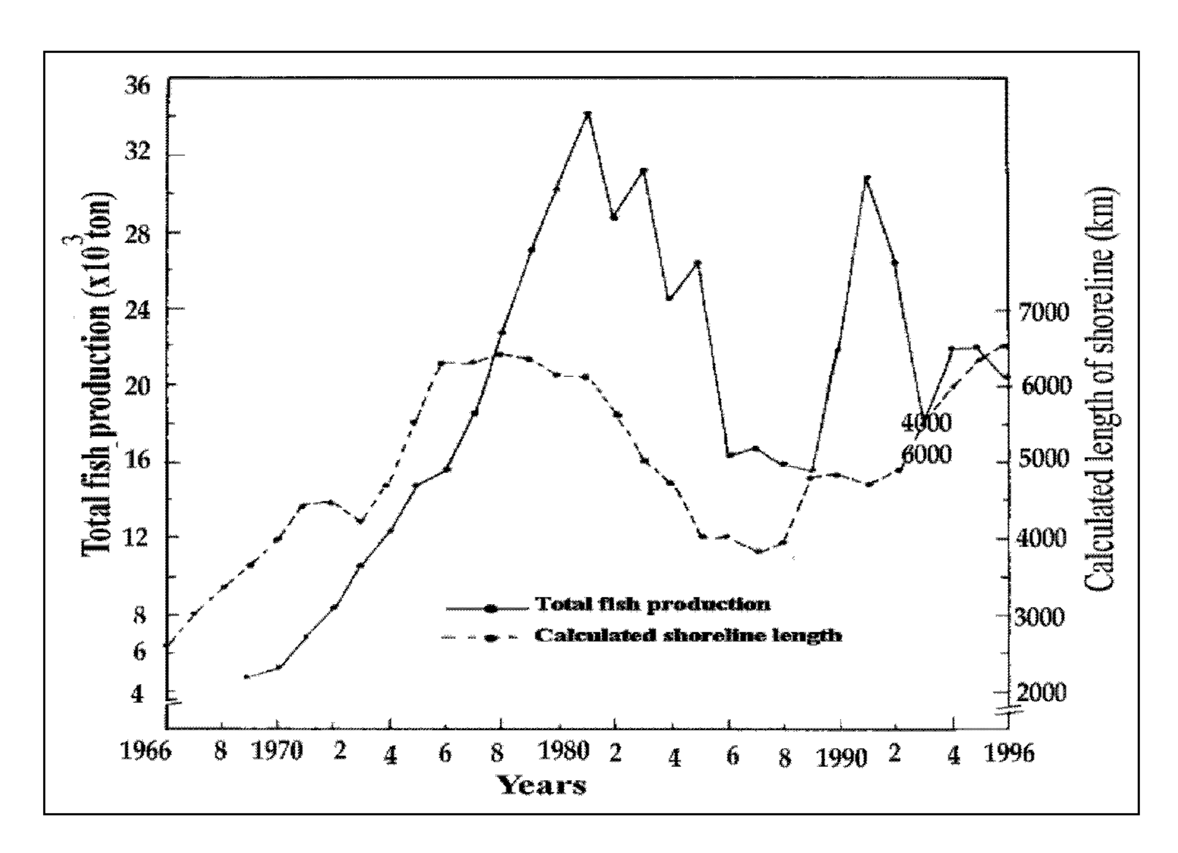


Fig. 171 **Relation between total fish production and calculated mean length of shoreline of Lake Nasser.**

Table 114 **Months of the main peaks in the catch and gonad index (GI) of *0 . niloticus* and *S. galilaeus* . (Mekkawy 1998).**

Catch & gonad index (GI)	Peak no. 1	2	3
Peaks in catch of year (Ahmad 1994)			
1983	March	August	
1984	March	August	November
1985	March	July	November
1989	March	September	December
1990	March	August	December
Peaks in GI of *O. niloticus* (Latif & Rashid 1972)			
Males	March	August	December
Females	April	September	
Peaks in GI of *S. galilaeus* (Abdel-Azim 1974)			
Males	April	September	
Females	February	June	
Peaks in GI of *O. niloticus* (Adam 1994, 1995a and b)			
Males	April	September	December
Females	April	September	

Fig. 172 **The relationship between female gonad index of *Oreochromis niloticus* and monthly tilapia yield of Lake Nasser in different years (based on data of Latif & Rashid (1972): *G1l;* Ahmad (1994) and Adam (1994,1995 a and b): *G12*).**

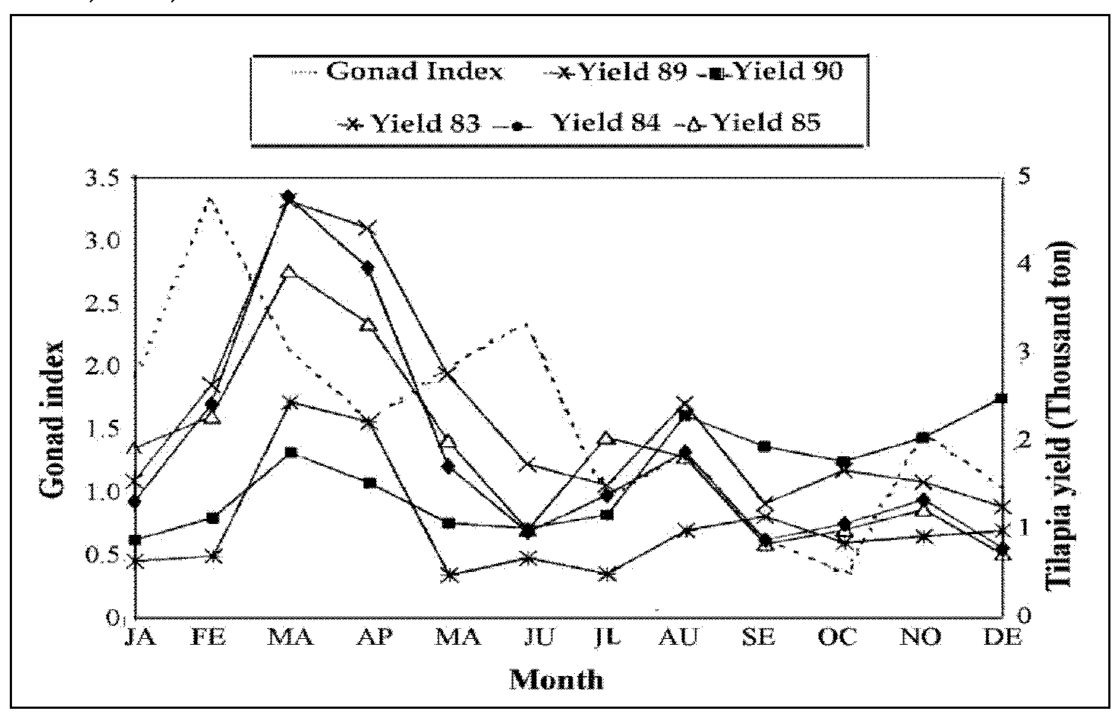


Fig. 173 **The relationship between female gonad index of *Sarotherodon galilaeus* and monthly tilapia yield of Lake Nasser in different years (based on data of Abdel-Azim (1974) & Ahmad (1994).**

The correlation between the catch of tilapiine species and gonad index (Table, 115) during different years (Mekkawy 1998) showed insignificant

correlations in the early years of Lake formation, while those of the latter years exhibited relatively high correlation (except for 1990-catch).

Table 115 **The correlation between the catch of tilapiine fishes and gonad index of *0. niloticus* and *S. galilaeus* of Lake Nasser (Mekkawy 1998) .**

Year	The correlation coefficients with gonad index of:			
	O. niloticus **(Latif & Rashid 1972)**	***0. niloticus*** **(Adam 1994)**	***0. niloticus*** **(Adam 1995a & b)**	***S. galilaeus*** **(Abdel-Azim 1974)**
1983	0.63	0.91	0.90	0.40
1984	0.53	0.87	0.85	0.39
1985	0.43	0.85	0.85	0.43
1989	0.58	0.73	0.65	0.00
1990	0.12	-0.27	-0.36	-0.51

RELATIONSHIP BETWEEN PROHIBITING FISHING AND MATURITY

From January to May, *0. niloticus* have maturity stages III-V representing 64.9% of the total mature fishes, while from 15th March to 15th May (prohibiting fishing period) the mature fishes represented 31.65% of the total mature fish examined per year and 48.77% of the total mature fish examined in the first five months (Table 116). Mekkawy (1998) suggested that the production of *0. niloticus is* mainly controlled by mature females during January-May. During the first six months (January-June), the percentage of mature *S. galilaeus* represented 63.6% of the total mature fish examined per year, while it formed only 17.5% during the prohibiting fishing period, and 27.52% of the mature fish during January-June. Considering these results and those of catch gonad-index, Mekkawy (1998) suggested that the prohibiting fishing period should be extended to be six months, from January to June. However, this suggestion is practically inapplicable. Fishing in Lake Nasser cannot be prohibited for more than two months - from March 15th to May 15th . This practice proved to be effective.

FISHING GEARS AND NETS

The fishing gears and nets used for fishing in Lake Nasser are as follows:

1. **Floating gill-nets (Sakarota).** These nets are designed to fish in surface waters.

The mesh size varies from 3 to 6 cm. The net length varies from 20 to 50 m and depth from 1.5 to 2 m. A number of nets (i.e. from 20 to 40) are stringed together to form a long net. The net is used for fishing raya *(Alestes* spp.) and kalb *(Hydrocynus* spp.). This fishery is operated every night and the catch is gutted and salted.

2. Trammel nets (Duk). The net length ranges from 10 to 20 m and 1.2 to 1.5 m deep. The outside walls have a mesh size of 30 to 40 cm and inside walls of 8 to 10 cm. The trammel net is piled up at the rear of the boat and is easily handled by a fisherman while another man rows the boat. The net is cast and set off against the rocky faces of the shoreline few meters away from the shore. The boat then moves in between shore and the net. A fisherman hits the surface of the water by using a pole. He also drums on the deck with his feet, sending vibrations into the water. Fishes, mainly *Tilapia* spp. (bolti), *Lates niloticus* (samoos), *Bagrus bajad* (bayad) and *Clarias spp.* (hout) drift into nets and get entangled. Fishing starts after darkness and continues till just before dawn. It is confined to shallow water ranging in depth from 1 to 2.5 m. Fishing using trammel nets is the main support for supply of fresh fish.

Table 116 **Frequencies and percentages of *O. niloticus (O.n.)* and S. *galilaeus (S.g.)* at maturity stages III-V in different months (based on studies of Abdel-Azim (1974) and Adam (1994).**

Month	No of fish examined at maturity stages III-V		% relative to total fish examined per month		% relative to total fish examined per year		Cumulative % relative to total fish examined per year	
	O. n.	*S. g.*	*O. n.*	*S. g.*	*O. n.*	*S. g.*	*O. n.*	*S. g.*
Jan.	28	41	51	85	9.1	16.9	9.1	16.9
Feb.	34	20	63	83	11.1	8.3	20.2	25.2
Mar.	45	17	87	94	14.7	7.0	34.9	32.2
Apr.	57	12	89	86	18.6	4.9	53.5	37.1
May	35	22	70	100	11.4	9.1	64.9	46.2
Jun.	14	42	51	100	4.6	17.4	69.5	63.6
Jul.	11	12	33	39	3.6	4.9	73.1	68.4
Aug.	7	19	46	43	5.5	7.9	78.6	76.4
Sept.	29	21	44	39	9.4	8.7	88	85.1
Oct.	16	4	26	11	5.2	1.7	93.2	86.8
Nov.	12	11	19	42	3.9	4.5	97.1	91.3
Dec.	9	21	20	72	2.9	8.7	100	100
Total	**307**	**242**			**100**	**100**		

3- Sunken gill nets (Kobak). The mesh size ranges from 10 to 20 cm. Some of them are as small as 4 m in length. The number of nets joined together is sometimes as many as 20 and the nets may be up to 10 m deep. They are usually set in khors but sometimes in open waters. The fish caught in these nets are *Lates niloticus* (samoos), *Oreochromis niloticus* and *Sarotherodon galilaeus* (bolti), *Labeo* spp. (lebeis), *Bagrus* spp. (bayad), *Barbus bynni* (benny) and *Clarias* spp. (karmout). Most of these fishes are sold as fresh fish. The nets are raised every second night or every night.

4- Beach seines (Gorrafa). The net is used for day-time fishing and catches mainly bolti *(Tilapia* spp.).

5- Long-line. The long-line fishing is operated to a limited extent and is more common in the southern part than in the northern part of the Lake. It is commonly used in deep waters to catch samoos and bayad. The fry and fingerlings of bolti and lebeis are used as bait.

Mesh selectivity curves of trammel net

Adam (1993) carried out experiments on the trammel nets with three mesh sizes, (8, 12 and 18 cm) in stretched measure, over the period of 1983 to 1990 in Lake Nasser. The latter author determined experimentally the mesh selectivities of the trammel net for *Oreochromis niloticus* and *Sarotherodon galilaeus* using Ishida's & McCombie's and Fry's methods. The results of the experiments are shown in Tables 117 & 118 and represented in Figs. 174 -177.

The mesh selectivity curves of the trammel net (Figs. 174-176) were not so clear for *0. niloticus* and *S. galilaeus* (Adam 1993). The figures show that the relative catching efficiency remarkably increased with the length and reached a peak and then gradually decreased as the length increased. Thereby, it was possible to roughly decide the optimum length for a certain mesh size from the curves. Adam (1993) analysed the mesh selectivity for the two fish species using the data obtained through the experiment and summerized his results in the following:

1. The optimum lengths of the fishes show good agreements for each mesh size between the mesh selectivity curves determined by the two methods.

2. The trammel net has a tendency to sharply select small-sized fish, as compared with large-sized ones in both fish species. This tendency is considered to be mainly due to relatively large fishes being entangled both by inside and outside nets.

3. It is likely that the mesh selectivity of the trammel net is weak, at least for the two fish species, compared with that of a gill net.

Table 117 **Number of *0. niloticus* caught by different mesh sizes of inside trammel net and mean of the maximum girth (Adam 1993).**

Fish length (cm)	Mesh size (cm)			Mean of max. girth (cm)
	8	12	18	
12.5-14.4 (13.5)	3	0	0	
14.5-16.4 (15.5)	15	1*	0(1)	16.3
16.5-18.4 (17.5)	22	1	0(1)	18.7
18.5-20.4 (19.5)	10	4	1	20.3
20.5-22.4 (21.5)	10	19	3	22.2
22.5 - 24.4 (23.5)	7	30	1	24.3
24.5 - 26.4 (25.5)	3	24	1	26.9
26.5 - 28.4 (27.5)	6	14	1	28.7
28.5 - 30.4 (29.5)	6	8	6	31.0
30.5-32.4 (31.5)	6	8	16	33.3
32.5 - 34.4 (33.5)	8	12	28	34.8
34.5-36.4 (35.5)	9	8	44	37.3
36.5 - 38.4 (37.5)	7	8	23	38.2
38.5 - 40.4 (39.5)	7	7	27	39.7
40.5-42.4(41.5)	2	5	10	42.1
42.5 - 44.4 (43.5)	3	1	10	44.8
44.5 - 46.4 (45.5)	1	1	4	

***(1): Shows one fish caught, for the calculation.**

Table 118 **Number of S. *galilaeus* caught by different mesh sizes of inside trammel net (Adam 1993).**

Fish length (cm)	Mesh Size	
	8 cm	12 cm
10.5 -12.4(11.5)	6	1
12.5 - 14.4 (13.5)	160	1
14.5 - 16.4(15.5)	303	6
16.5 - 18.4(17.5)	160	22
18.5 - 20.4 (19.5)	89	82
20.5 -22.4(21.5)	54	94
22.5 - 24.4 (23.5)	43	61
24.5 - 26.4 (25.5)	22	50
26.5 - 28.4 (27.5)	8	13

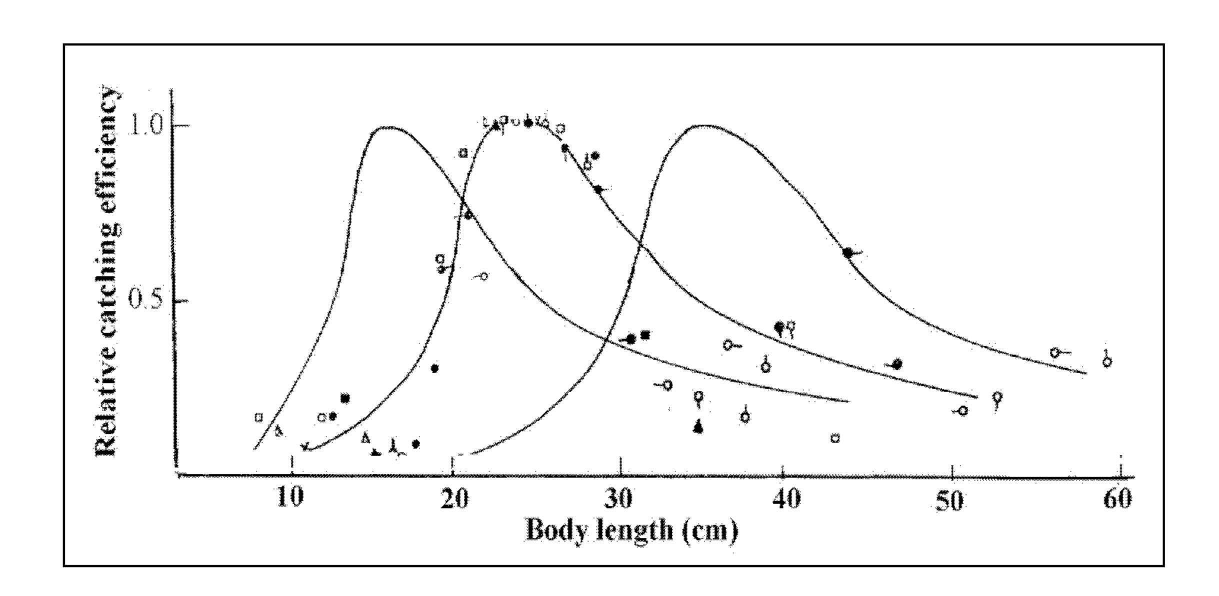


Fig. 174 **Mesh selectivity curve of *O. niloticus* for the trammel net. Plotted points represent the data of 12 cm inside mesh size, Marks show the size classes (Adam 1993). □ 13.5 cm △ 15.5 cm x 17.5 cm ● 19.5 cm ■ 21.5 cm △ 23.5 cm 25.5 cm 27.5 cm ●- 29.5 cm -● 31.5 cm -o 33.5 cm ♀ 35.5 cm o- 37.5 cm 39.5 cm 41.5 cm 43.5 cm.**

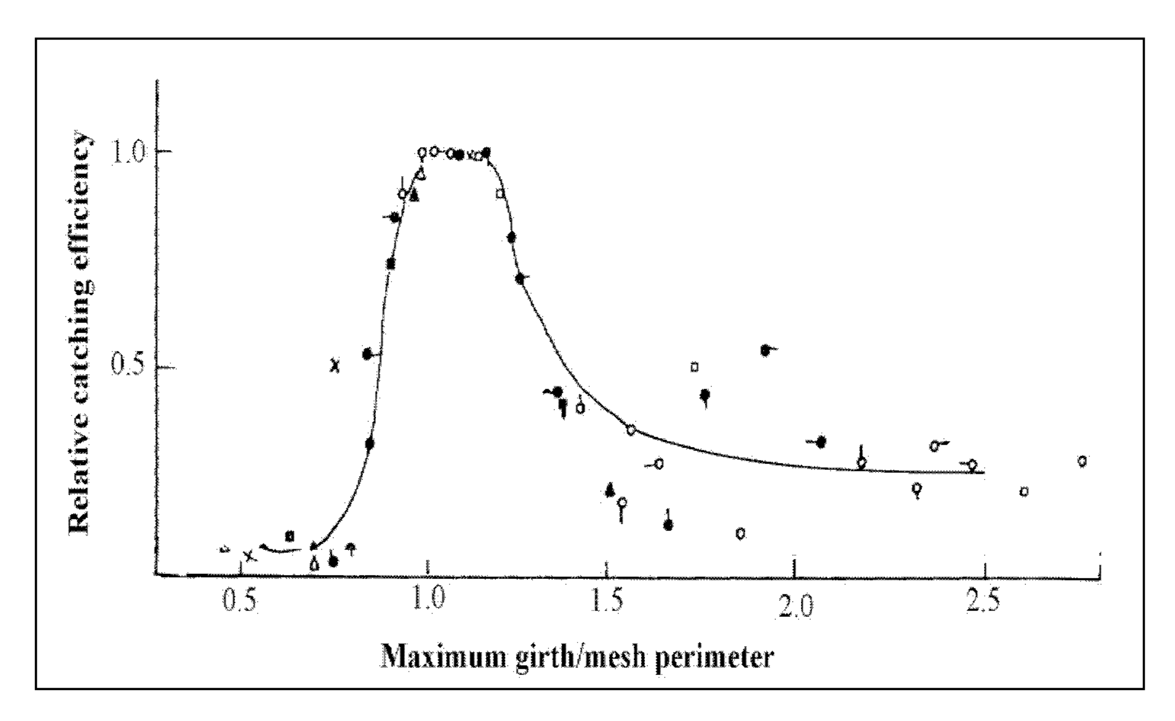


Fig. 175 **Mesh selectivity curve of *O. niloticus* for the trammel net. Plotted points represent the size classes (Adam 1993).**

△ 15.5 cm x 17.5 cm ● 19.5 cm ■ 21.5 cm △ 23.5 cm 25.5 cm 27.5 cm ●- 29.5 cm -● 31.5 cm 33.5 cm ♀ 35.5 cm o- 37.5 cm -o 39.5 cm □ 41.5 cm o 43.5 cm.

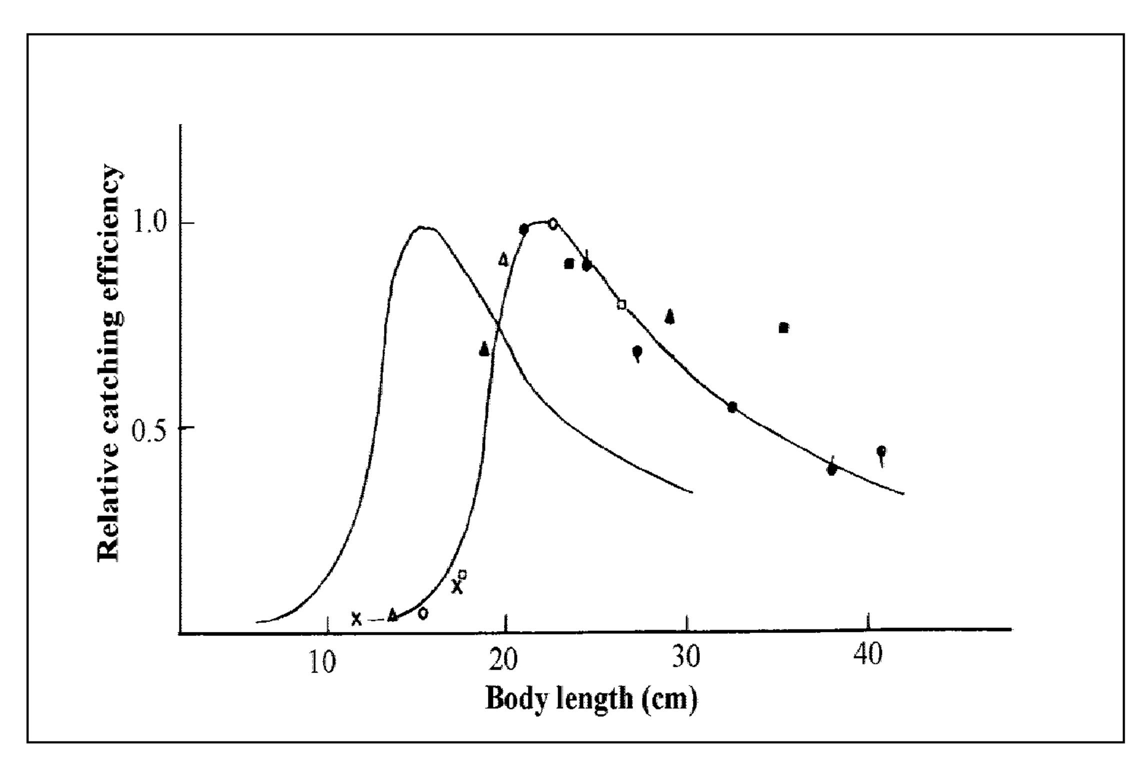


Fig. 176 **Mesh selectivity curve of *S. galilaeus* for the trammel net. Plotted points represent the data of 12 cm inside mesh size. Marks show the size classes (Adam 1993). ✕ 11.5 cm △ 13.5 cm ○ 15.5 cm □ 17.5 cm ▲ 19.5 cm ● 21.5 cm ■ 23.5 cm ⍋ 25.5 cm ⍒ 27.5 cm.**

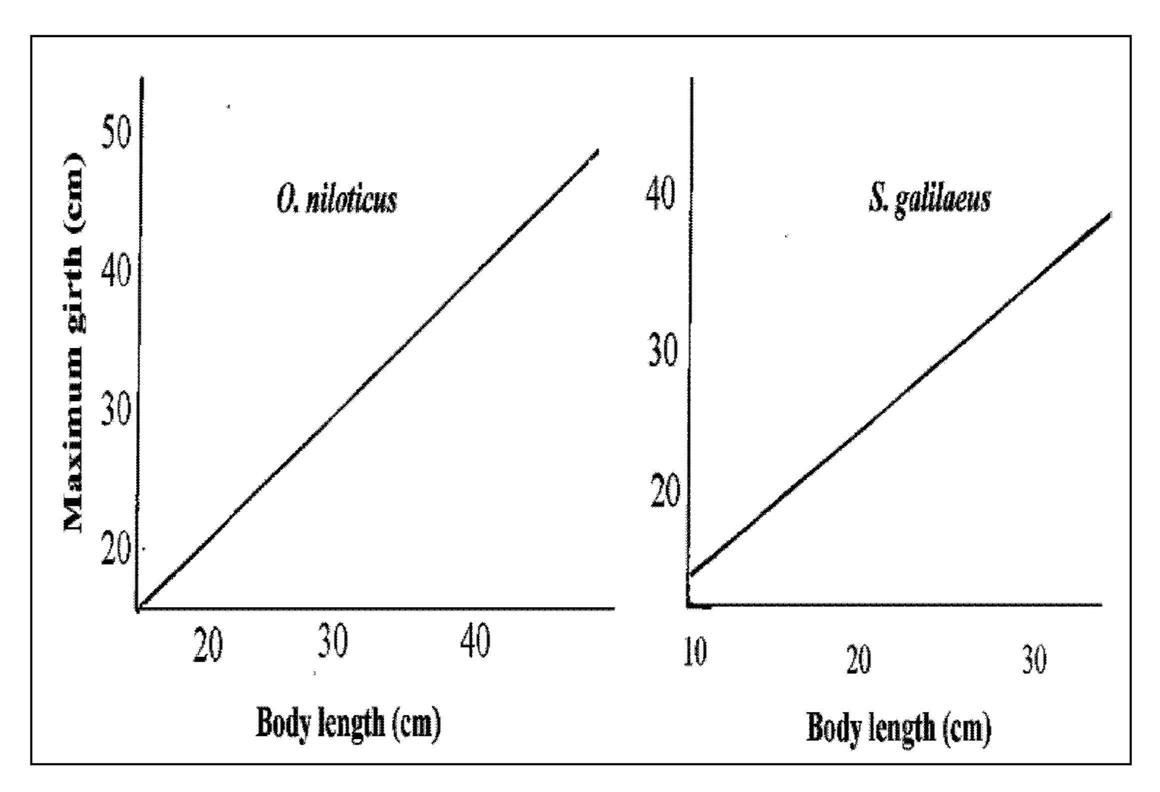


Fig. 177 **Relation between body length of *0. niloticus* and S. *galilaeus* and maximum girth of net (Adam 1993).**

RELATIONSHIP BETWEEN EFFORT AND BIOMASS

Mekkawy (1998) described the effort-biomass relationship for *0. niloticus* and S. *galilaeus* (Fig. 178) by the following equations :

For *0. niloticus*

Biomass (kg) = 4,506,801 + 39,236.75 Effort (boats) where r = 0.577

For *S. galilaeus*

Biomass (kg) = -2,384,143 + 21,503.39 Effort (boats) where r = 0.662

The latter author concluded that fishing can not be considered the only factor or the major one that controls biomass. Furthermore, fishing represents only 33 and 44% of the total effect for *0. niloticus* and *S. galilaeus* respectively.

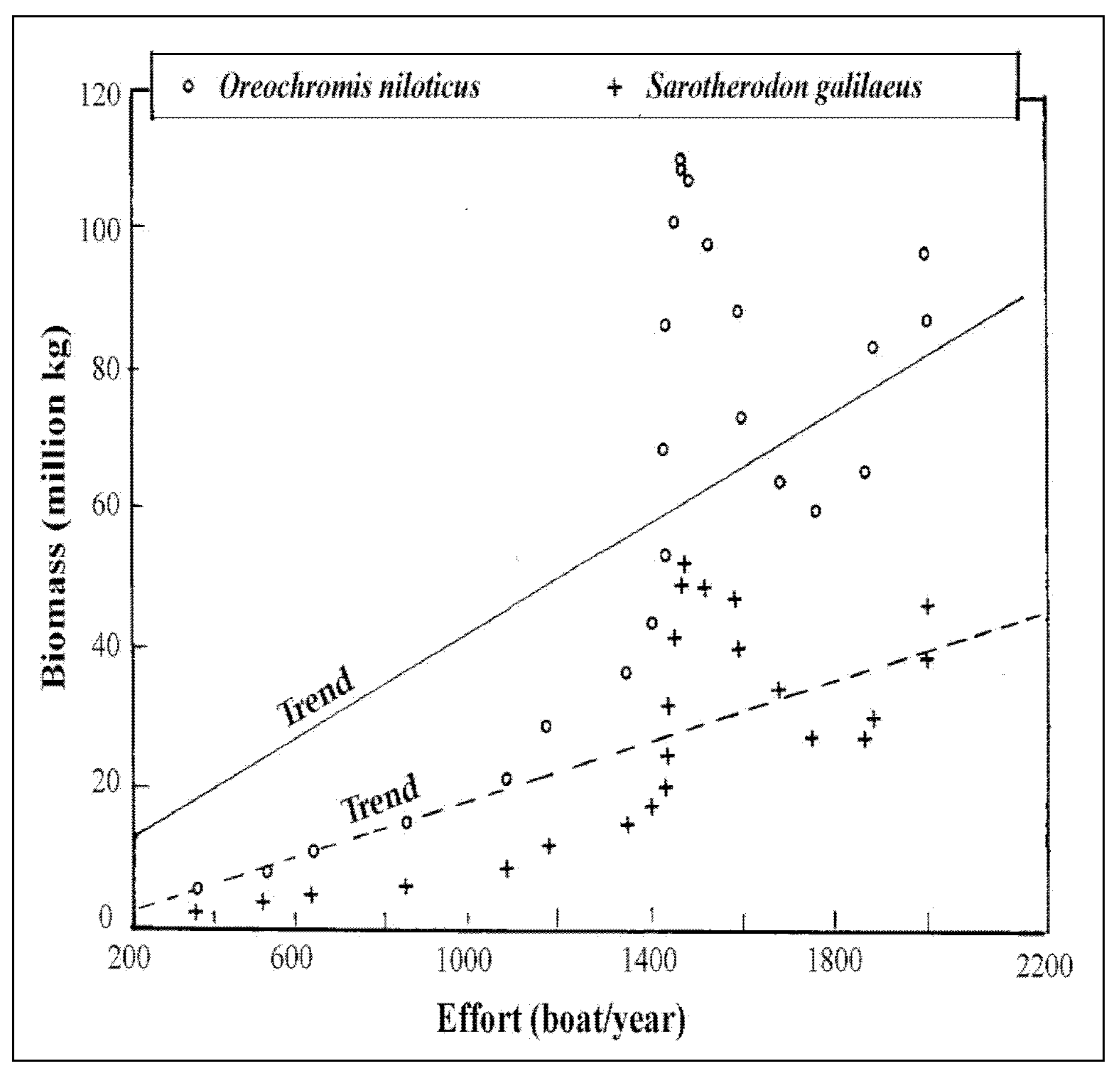


Fig. 178 **The Effort-biomass relationship of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser (Mekkawy 1998).**

VIRTUAL POPULATION ANALYSIS (VPA) AND TURNOVER RATIO

VPA looks at the populations of *0. niloticus* and *S. galilaeus* in a historic perspective. During 1966-1992, the recruits, abundance and biomass of tilapiine species were estimated (Tables 119 and 120 - Mekkawy 1998). The trend of increase in the yield, abundance and biomass per hectare with respect to the corresponding total area of the Lake and 20% of such area (the true exploited spawning -fishing area) are presented in Tables 119 and 120. The Lake yield of the two tilapiine species was relatively high, when considering the true exploited area. The variation in the abundance of the two species may be caused by the variable changes in the rate at which their individuals were added through births or lost through death (Mekkawy 1998).

The latter author determined the fish production of *0. niloticus* and *S. galilaeus* as a function of their mean growth in the cohort, measured by the specific growth rate and the total mortality rate (Tables 119 and 120). The ratio of production to biomass (turnover ratio) was relatively high in the first years of Lake impoundment. However, the turnover ratio of *S. galilaeus* was lower than that of *0. niloticus* through the whole period. The Lake yield of *0. niloticus* and *S. galilaeus,* was smaller than the biomass (Table 119 and 120), which means that their fisheries did not experience difficulties due to the increasing effort during 1966-1991. However, in 1992 the biomass of both species slightly differed from the yield, which means the start of such difficulties. Hence, the fisheries of tilapiine species should be carefully monitored because higher fishing efforts together with a further series of droughts could bring ruin to these fisheries.

GEAR SELECTIVITY

VPA produced an array of estimates of F-values (i.e. fishing pattern). During 1966 -1994, Mekkawy (1998) considered only the fishing pattern of 1979-cohort (since it was with a maximum value of recruitment) for gear selectivity / recruitment curves. F-values of 1979-cohort of *0. niloticus* were 0.005, 0.076, 0.852, 1.124, 2.638 and 1.135 for age groups I, II, III, IV, V and VI respectively. Those of *S. galilaeus* were 0.01,0.312 , 2.864 , 3.403 and 2.579 for age groups I, II, III, IV and V respectively.

Mekkawy (1998) determined the selection curves of *0. niloticus* and *S. galilaeus* (Figs. 179 and 180) and observed that $L_{25\%}$, $L_{50\%}$ and $L_{75\%}$ were 26.25 , 30.42 and 34.58 cm respectively for *0. niloticus* and were 15.26, 16.49 and 17.72 cm respectively for *S. galilaeus,* supposing the trawl fishing was in operation.

According to the length distribution of *0. niloticus* and *S. galilaeus* obtained by Mekkawy *et al.* (1994), Mekkawy & Mohamad (1995) and Shenouda *et al.* (1995) the Lc ($L_{50\%}$) was also estimated by Mekkawy (1998). Such length decreased with time for both species, and these values of Lc refer to the continuous decrease in mesh size used throughout 1970-1994.

Table 119 **The annual yield, biomass, abundance, production and turnover ratio of *0. niloticus* with respect to total area (100%) and the actual exploited area (20%) of Lake Nasser in 1966-1992. (Mekkawy 1998).**

Year	Yield (kg/ha)		Yield (no./ha)		Biomass (kg/ha)		Density (no./ha)		Production (kg/ha)		Turnover ratio (P/B)
	% of Lake Nasser's area										
	100%	20%	100%	20%	100%	20%	100%	20%	100%	20%	
1966	3.6	18.2	1.9	9.5	56.8	283.9	68.2	340.9	35.2	175.9	0.620
1967	2.1	10.6	1.1	5.6	33.2	165.8	39.4	196.8	11.5	57.4	0.346
1968	2.2	11.1	1.2	5.8	34.3	171.4	38.6	192.8	12.7	63.6	0.371
1969	4.8	24.0	2.5	12.5	38.6	193.0	42.2	211.2	14.5	72.3	0.375
1970	5.1	25.5	2.7	13.3	47.1	235.4	52.9	264.3	17.1	85.5	0.363
1971	5.8	29.1	3.0	15.2	59.0	295.2	67.1	335.5	19.0	95.0	0.322
1972	8.3	41.4	4.3	21.6	89.8	448.8	99.8	499.0	28.9	144.7	0.322
1973	14.9	74.3	7.8	38.9	123.4	617.2	132.0	659.9	38.3	191.5	0.310
1974	13.1	65.7	9.5	47.7	132.3	661.6	138.1	690.7	34.2	170.9	0.258
1975	14.0	69.8	10.1	50.6	127.4	636.8	133.9	669.7	31.0	155.2	0.244
1976	14.2	70.9	10.3	51.4	147.6	738.2	160.0	800.0	38.1	190.6	0.258
1977	15.1	75.5	10.9	54.7	186.9	934.4	201.6	1008.0	47.4	237.1	0.254
1978	22.3	111.4	16.2	80.8	223.3	1116.3	231.4	1157.1	60.8	304.1	0.272
1979	30.4	152.1	22.1	110.3	259.3	1296.6	260.4	1302.1	75.7	378.4	0.292
1980	35.3	176.4	25.6	127.9	271.1	1355.5	262.2	1311.1	85.3	426.5	0.315
1981	42.8	214.1	31.0	155.2	271.6	1357.8	260.7	1303.7	75.5	377.3	0.278
1982	34.8	173.9	25.2	126.1	261.0	1305.0	249.1	1245.4	88.0	440.1	0.337
1983	42.7	213.3	30.9	154.7	251.8	1259.0	232.4	1161.8	76.5	382.5	0.304
1984	38.7	193.6	28.1	140.4	237.3	1186.4	215.2	1076.0	87.2	435.8	0.367
1985	45.0	224.8	32.6	163.0	234.6	1173.2	215.0	1075.1	81.5	407.7	0.348
1986	33.4	166.9	24.2	121.0	237.6	1187.8	232.3	1161.6	88.3	441.3	0.372
1987	33.2	166.1	24.1	120.5	255.6	1278.0	260.8	1304.0	78.9	394.4	0.309
1988	35.6	177.9	25.8	129.0	341.1	1705.4	369.8	1848.9	93.0	464.8	0.273
1989	22.1	110.5	16.0	80.1	271.1	1355.4	286.6	1432.8	57.9	289.7	0.214
1990	33.1	165.7	24.0	120.2	280.0	1400.0	257.4	1286.8	69.2	346.2	0.247
1991	50.0	249.8	36.2	181.2	205.9	1029.5	139.0	694.8	77.2	386.0	0.375
1992	45.2	225.8	32.8	163.8	107.1	535.6	55.7	278.3	64.8	323.8	0.605

Table 120 **The annual yield, biomass, abundance, production and turnover ratio of S. *galilaeus* with respect to total area (100%) and the actual exploited area (20%) of Lake Nasser in 1966-1992. (Mekkawy 1998).**

Year	Yield (kg/ha)		Yield (no./ha)		Biomass (kg/ha)		Density (no./ha)		Production (kg/ha)		Turnover ratio (P/B)
	% of Lake Nasser's area										
	100%	20%	100%	20%	100%	20%	100%	20%	100%	20%	
1966	2.7	13.3	3.8	18.9	13.7	68.7	20.2	101.2	7.1	35.6	0.517
1967	1.6	7.8	2.2	11.0	9.1	45.7	13.9	69.7	2.2	11.0	0.242
1968	1.6	8.1	2.3	11.5	10.8	54.0	16.0	79.8	2.6	13.2	0.245
1969	3.5	17.5	5.0	24.9	13.2	65.8	18.5	92.7	3.3	16.7	0.254
1970	3.7	18.6	5.3	26.4	15.0	74.8	21.3	106.3	4.0	20.0	0.268
1971	4.3	21.3	6.0	30.2	18.4	91.8	26.6	133.1	3.9	19.5	0.212
1972	6.0	30.2	8.6	42.9	27.5	137.4	39.2	196.2	5.7	28.4	0.207
1973	10.8	54.2	15.4	77.1	38.4	192.2	53.8	268.8	6.9	34.5	0.179
1974	9.6	47.9	14.9	74.6	39.7	198.4	55.5	277.3	6.1	30.5	0.154
1975	10.2	50.9	15.8	79.2	37.2	186.1	51.2	256.1	5.1	25.4	0.137
1976	10.3	51.7	16.1	80.5	40.9	204.4	57.7	288.5	6.5	32.3	0.158
1977	11.0	55.1	17.1	85.7	52.2	262.3	75.1	375.6	7.6	38.1	0.145
1978	16.2	81.2	25.3	126.4	67.7	338.6	94.9	474.7	10.2	50.9	0.150
1979	22.2	110.9	34.5	172.6	84.7	423.5	117.6	587.8	13.5	67.5	0.159
1980	25.7	128.7	40.1	200.3	92.5	462.7	125.4	626.8	16.2	81.1	0.175
1981	31.2	156.2	48.6	243.0	95.6	478.2	128.5	642.4	13.5	67.5	0.141
1982	25.4	126.9	39.5	197.4	91.3	456.5	123.8	619.2	17.5	87.6	0.192
1983	31.1	155.6	48.4	242.2	94.1	470.3	125.3	626.4	14.3	71.5	0.152
1984	28.3	141.3	44.0	219.8	89.3	446.4	117.9	589.7	18.4	91.9	0.206
1985	32.8	164.0	51.0	255.2	88.1	440.4	114.8	574.1	17.0	85.1	0.193
1986	24.4	121.8	37.9	189.5	80.7	403.3	108.8	544.0	19.4	96.9	0.240
1987	24.2	121.2	37.7	188.6	79.7	398.6	107.5	537.6	15.7	78.3	0.196
1988	26.0	129.8	40.4	201.9	94.9	474.5	132.6	662.8	16.9	84.6	0.178
1989	16.1	80.6	25.1	125.4	79.2	396.2	114.4	572.2	8.1	40.5	0.102
1990	24.2	120.9	37.6	188.1	101.1	505.6	139.8	698.8	10.2	50.9	0.101
1991	36.4	182.2	56.7	283.6	92.0	460.1	112.7	563.4	14.6	72.9	0.158
1992	32.9	164.7	51.3	256.4	51.9	259.6	56.8	283.9	15.5	77.6	0.299

Mekkawy (1998) estimated the optimum length of *0. niloticus* as 30.1 cm with a selection factor of 2.3684, supposing the trammel-net fishing. Hence, the optimum lengths were 18.94 , 28.42 and 42.63 cm corresponding to 8 - , 12- and 18- mesh size trammel nets respectively in current operations.

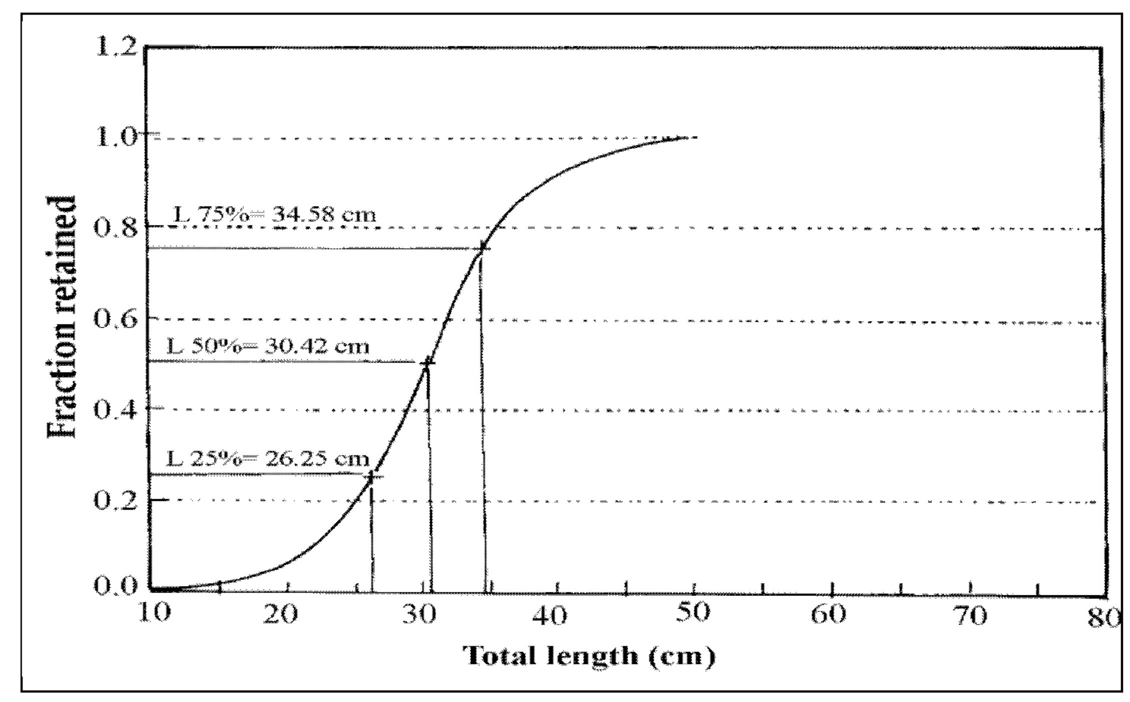


Fig. 179 **Trawl selection curve derived from VPA of *Oreochromis niloticus* as a function of body length (Mekkawy 1998).**

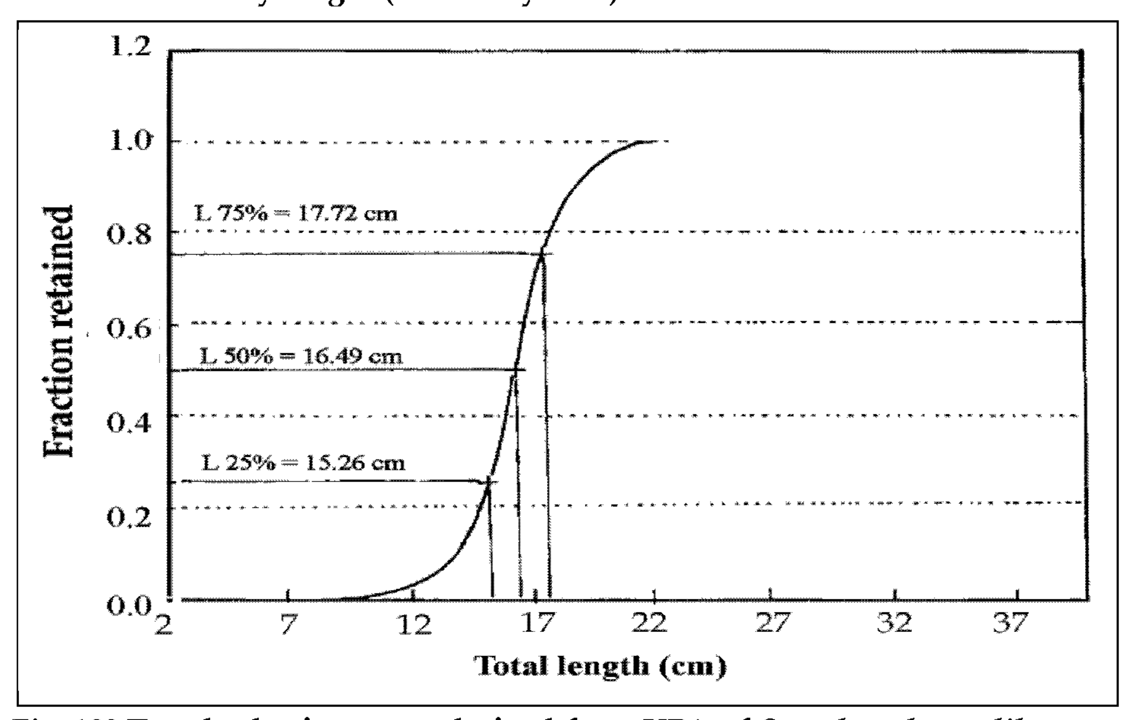


Fig. 180 **Trawl selection curve derived from VPA of *Sarotherodon galilaeus* as a function of body length (Mekkawy 1998).**

These VPA values reflect the long term nature of the data especially those of the first period of Lake formation. The optimum lengths estimated from experimental catch by these trammel nets were 15.45, 23.17 and 34.76 cm for 8 , 12 and 18 mesh size respectively with a selection factor of 1.93116 (Fig. 181). This means that the optimum lengths estimated from experimental catch of the tilapiine species combined were 18.83, 28.24 and 42.36 cm for 8; 12 and 18 mesh sizes respectively. However, Adam (1993) estimated the optimum lengths, according to Ishida (1962), to be 17.0 , 25.5 and 37.0 cm for 8 , 12 and 18 mesh sized trammel nets respectively.

Mekkawy (1998) recorded the VPA-based estimate of the mean optimum length of *S. galilaeus* as 18.45 cm with a selection factor of 1.8448. Hence, the optimum lengths corresponding to 8 and 12 mesh sizes of gill nets in current operation were 14.76 and 22.14 cm respectively and these estimates were lower than those of experimental catch. The latter author showed that the optimum lengths estimated from gill net experimental catch were 16.22 and 24.33 cm for 8 and 12 mesh-sized gill nets respectively with a selection factor of 2.027 (Fig. 182). Such lengths were 15.5 and 23.0 cm for 8 and 12 mesh-sized trammel nets respectively (Adam 1993).

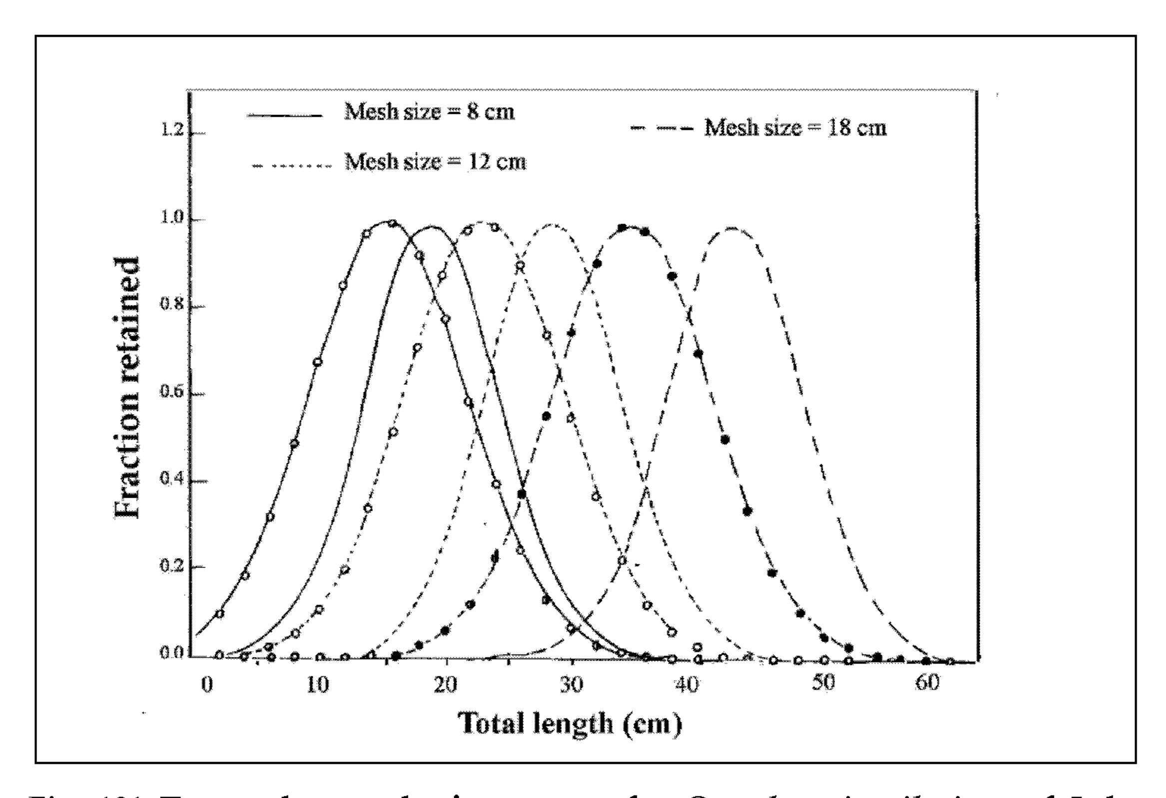


***Fig. 181* Trammel net selection curves for *Oreochromis niloticus* of Lake Nasser (unmarked lines: based on Lm derived from VPA, marked lines: based on Lm derived by analysis of Adam's (1993) raw data according to Sparre *et al.* (1992), (Mekkawy 1998).**

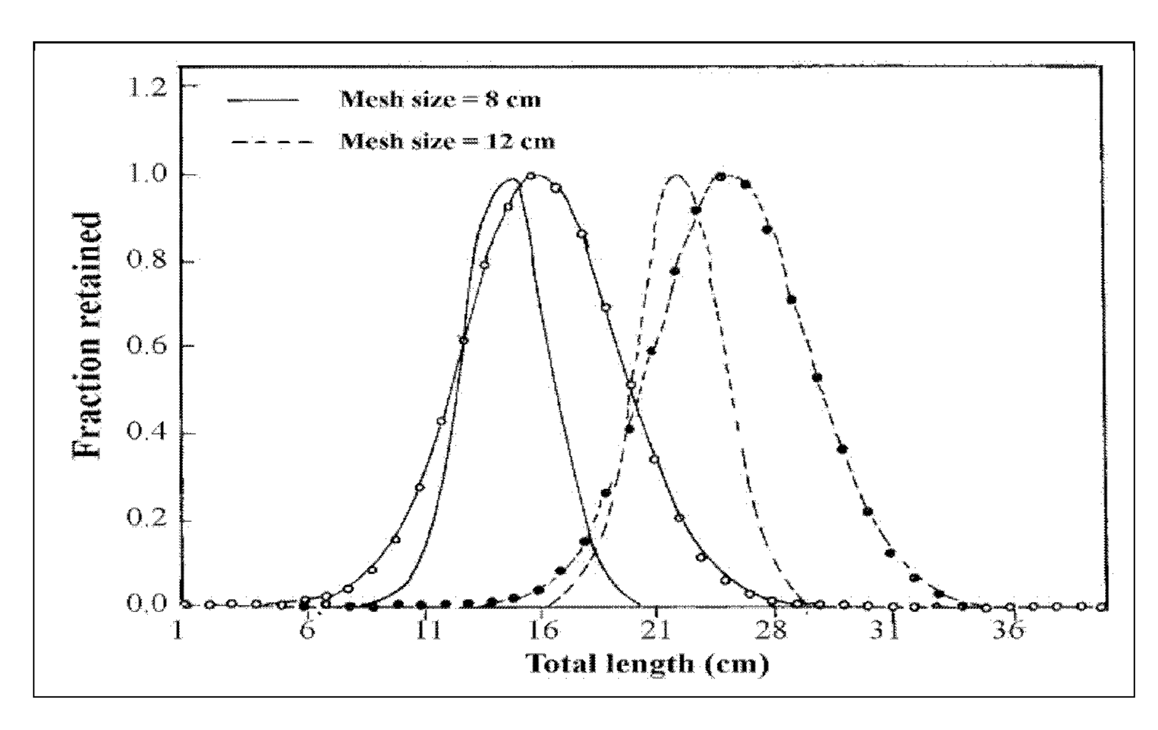


Fig. 182 **Trammel net selection curves for *Sarotherodon galilaeus* of Lake Nasser (unmarked lines: Lm derived from VPA, marked lines: based on Lm derived by analysis of Adam's (1993) raw data according to Sparre *et al.* (1992), (Mekkawy 1998).**

POPULATION CHARACTERISTICS

There were different patterns of growth of *0. niloticus* and *S . galilaeus* during 1970-1990 (Tables 121 and 122). These growth patterns reflect different growth performance indices (ϕl). Thus, during the first period of Lake formation, isometric and positive allometric growth were recorded for the two fish species, whereas negative allometry was observed during the latter years (Tables 121 and 122 - Mekkawy, 1998). In general, the maximum length estimated for the two tilapiine species exhibited a decrease trend with the progression of years. The latter author attributed the reduction in the average size of tilapiine species to two reasons. The first one is the high exploitation rate, while the second possible reason is that large fish migrate from shallow to deep waters during the fishing process. It is suggested to carry further detailed studies on these species to give a satisfactory explanation for the gap between observed maximum length and Lα . The variation in the aforementioned growth parameters reflects the variation in age composition (Table 123).

Other population characteristics of *0 . niloticus, S . galilaeus* and *Lates niloticus* from Lake Nasser, are calculated by Mekkawy (1998) and are presented later in the estimation of the maximum sustainable yield (MSY), using some population characteristics. The actual total mortality rate (A) of both *Tilapia* spp. in Lake Nasser during different years, derived from or based on data of Mekkawy (1998), are presented in Table 124 and Fig. 183.

Table 121 **Estimates of growth parameters and the index of growth performance of *O. niloticus* of Lake Nasser, derived from or based on data of different authors (Mekkawy 1998) .**

Author	Growth parameters: von Bertalanffy equation ** L(t)=Lα[1-exp(-k(t-to))]				Growth performance*	Power function equation ** W=aL"	
	k(per year)	to (years)	Lα (cm)	Wα (g)	ϕ[1]	n	a
Abdel-Azim (1974)	0.1925	-0.9746	81.57	12289	7.16	3.023++	0.0205
Latif & Khallaf (1987)[a]	0.340	0.59	53.2 (TLα =66.73)	5312.8	6.87	2.8789+	0.0571
Mekkawy *et al.* (1994)	0.0875	-0.9315	76.38	8147	6.24	2.9310+	0.02466
Yamaguchi *et al.* (1990) (Khor Gazal)[a]							
Males	0.384	-0.359	42.77 (TLα =53.94)		6.55		
Females	0.545	-0.117	36.90 (TLα =46.75)		6.61		
Agaypi (1992a) Khors:							
El-Ramla	0.166	-0.94	68.7		6.66		
Gazal	0.472	0.09	47.0		6.95		
El-Allaqi	0.482	0.11	45.2		6.89		
Korosko	0.263	0.44	45.0		6.64		
All khors	**0.275**	**0.75**	**52.0**	**4697.3**	**6.61**	**2.72+**	**0.101**

****: length used in all cases is total length with the exception that "a" length used is standard length.**

***ϕ=In k+2 In Lα (Pauly & Munro 1984); + and ++ = negative allometric and isometric growth respectively.**

Table 122 **Estimates of growth parameters and the index of growth performance of *S. galilaeus* of Lake Nasser, derived from or based on data of different authors (Mekkawy, 1998).**

Author	Growth parameters: von Bertalanffy equation ** $L(t)= L\alpha [1-exp(-k(t-to))]$				Growth performance*	Power function equation ** $W=aL^n$	
	k (per year)	to (years)	Lα (cm)	Wα (g)	ϕ^1	n	a
Abdel-Azim (1974)	0.0365	-6.910	56.89	3047	4.77	3.124+++	0.0162
Latif & Khallaf (1987)[a]	0.27	-1.74	37.6 (TLα =48.75)	1946	5.94	2.2503+	0.5553
Mekkawy & Mohamad (1995)	0.0908	-3.2444	38.33	1097	4.89	2.8687+	0.0315
Yamaguchi *et al.* (1990) (Khor Gazal)[a]							
Males	0.681	-0.052	27.29 (TLα =35.6)		6.23		
Females	0.525	--0.195	28.82 (TLα =37.58)		6.08		
Agaypi (1992a)							
Khors:							
Gazal	0.216	-0.93	36.0		6.63		
El-Allaqi	0.631	0.04	31.0		6.41		
Korosko	0.333	-0.46	33.5		5.92		
All khors	**0.194**	**-0.64**	**42.0**	**2741**	**5.84**	**2.60+**	**0.125**

**: length used in all cases is total length with the exception that "a" length used is standard length.

*ϕ=In k+2 In Lα (Pauly & Munro 1984); + and ++ = negative allometric and isometric growth respectively.

Table l23 **Percentages of occurrence of different age groups of** ***O . niloticus*** **and** ***S galilaeus*** **of Lake Nasser in 1965-1990 (Mekkawy, 1998).**

Author	Age groups									
	I	II	III	IV	V	VI	VII	VIII	IX	Mean
					O . niloticus					
Abdel-Azim (1974) in 1965-1970	30.02	51.76	13.32	4.90						1.83
Latif & Khallaf (1987)in:										
1984	3.20	29.20	30.40	13.10	12.20	7.70	2.90	0.90	0.40	3.44
1985	18.30	41.00	26.60	11.50	2.60					2.39
Mekkawy *et al.* (1994) in 1989-1990	2.22	16.76	56.65	19.94	4.29	0.14				3.08
Adam (1994) in 1989-1990	21.66	40.82	31.79	5.73						2.22
					S. galilaeus					
Abdel-Azim (1974) in 1972-1973	56.58	31.39	11.29	0.74						1.56
Latif & Khallaf (1987) in:										
1984	14.20	65.40	15.40	3.50	1.40	0.10				2.13
1985	30.10	37.70	30.00	2.30						2.03
Mekkawy & Mohamed (1995) in 1989-1990	1.40	31.10	62.96	4.43	0.11					2.71
Adam (1994) in 1989-1990	57.10	39.16	3.74							1.47

Table 124 **Actual total mortality rate (A) of *Oreochromis niloticus* and *Sarotherodon galilaeus* in Lake Nasser during different years (1966-1992). Derived from or based on data of Mekkawy (1998).**

Year	Actual total mortality rate (A)	
	0. niloticus	*S. galilaeus*
1966	0.535	0.291
7	0.583	0.424
8	0.625	0.533
9	0.651	0.592
1970	0.702	0.698
1	0.746	0.778
2	0.763	0.805
3	0.811	0.875
4	0.817	0.882
5	0.846	0.916
6	0.810	0.873
7	0.810	0.873
8	0.791	0.849
9	0.800	0.860
1980	0.807	0.869
1	0.872	0.940
2	0.826	0.892
3	0.860	0.929
4	0.827	0.894
5	0.838	0.906
6	0.804	0.865
7	0.804	0.865
8	0.805	0.866
9	0.894	0.958
1990	0.894	0.958
1	0.872	0.941
1992	0.859	0.927

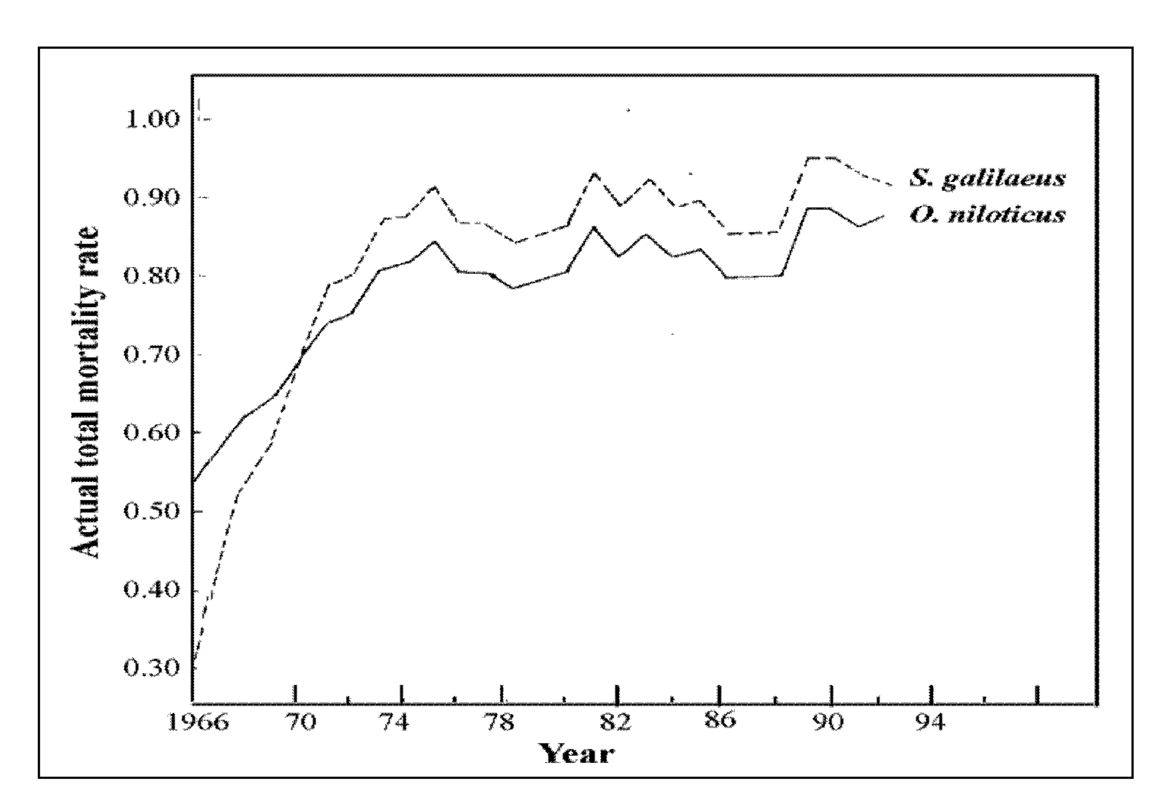


Fig. 183 **Actual total mortality rate of *O. niloticus* and *S. galilaeus* during 1966 -1992 in Lake Nasser.**

DEMOGRAPHIC CHARACTERISTICS

Mekkawy (1998) built up the life tables of 1979 and 1985-cohorts of *O. niloticus* and *S . galilaeas* (Table 125) according to Murray (1979), Krebs (1985) and Wootton (1991). The related parameters are given in Table 125. The survivorship curves of 1979-cohorts of the two tilapiine species exhibited two different curves (Mekkawy 1998-Figs. 184 and 185). That of *0 . niloticus* occupies an intermediate position between type I and type II curves of Krebs (1985). According to the latter author, type I curve represents populations with very little loss for most of the life span and then high losses of older organisms, whereas type II curve, the diagonal survivorship curve, implies a constant rate of mortality independent of age. The survivorship curve of *S. galilaeus* was close to type I.

Table 125 shows the growing nature in the abundance of *0 . niloticus* and *S. galilaeus* . Slight differences in the population characteristics were observed. Figs. 186 and 187 show the relationships between the abundance of adult stock of both tilapiine species in year Y and its abundance in year Y+1 during 1966-1992 (Mekkawy 1998). The relationship was evaluated according to the equation:

$$N_y + 1 = \lambda \ N_y \text{ (Wootton 1991).}$$

Table 125 **Population parameters of** ***0. niloticus*** **and S.** ***galilaeus*** **of Lake Nasser based on life tables of their 1979 - and 1985 - cohorts (Mekkawy 1998).**

Parameter	*O. niloticus*		*S. galilaeus*	
	1979-cohort	1985-cohort	1979-cohort	1985-cohort
Ro	1746	2079	2978	4766
rm	4.57	4.57	4.90	4.89
b	9.76	9.75	11.48	11.45
d	5.19	5.18	6.58	6.56
λ	96.37	96.13	133.60	132.93
T	2.09	2.36	2.02	2.51

Ro = net reproductive rate , rm = intrinsic or maximum rate of increase, b = instantaneous birth rate, d = instantaneous death rate; λ = finite rate of increase; T = generation length of population .

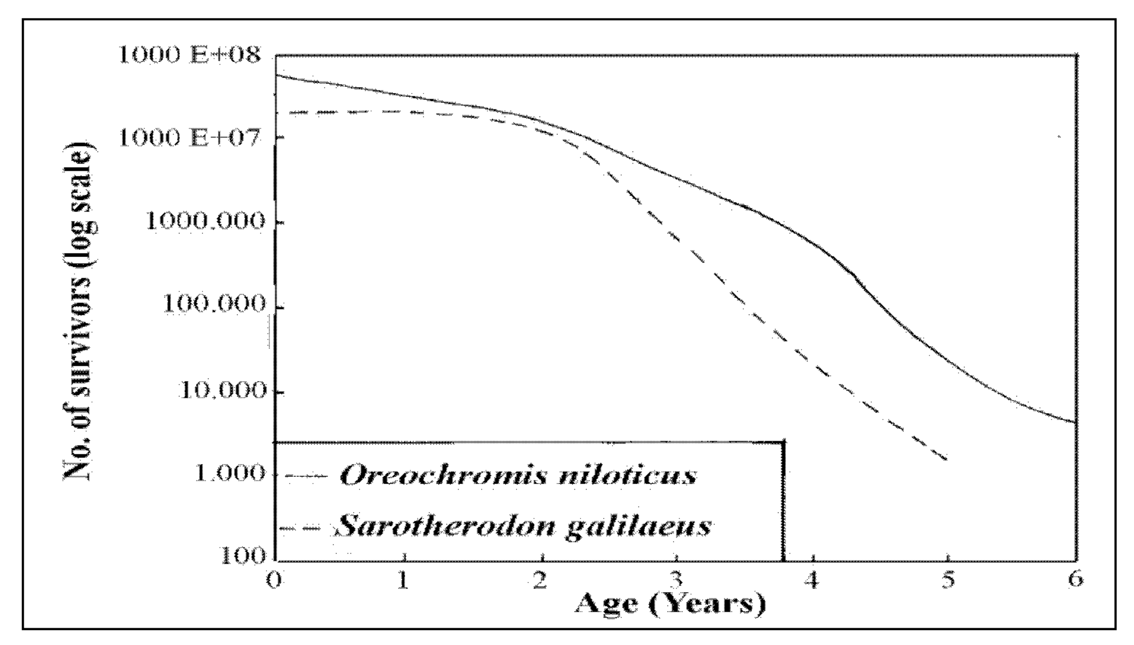


Fig. 184 **Survivorship curves (log scale) of 1979-cohorts of** ***Oreochromis niloticus*** **and** ***Sarotherodon galilaeus*** **of Lake Nasser (Mekkawy 1998).**

Comparing λ values of Table 125 with those derived from the relationships between the abundance of year Y (Ny) and abundance of year Y + 1 (Ny +1), Mekkawy (1998) concluded that there was a great loss in the pre-recruit stages of both tilapiine species, which was emphasized by the S / R - relationships. Figs. 186 and 187 show general trends towards increase in the abundance relationships in 1966-1992. The latter author concluded that high fecundity, reflected by the aforementioned parameters and long breeding season (Table 114) of these tilapiine species can be considered an adaptation

to a short life and to colonize and exploit the fluctuating and unpredictable environment of Lake Nasser.

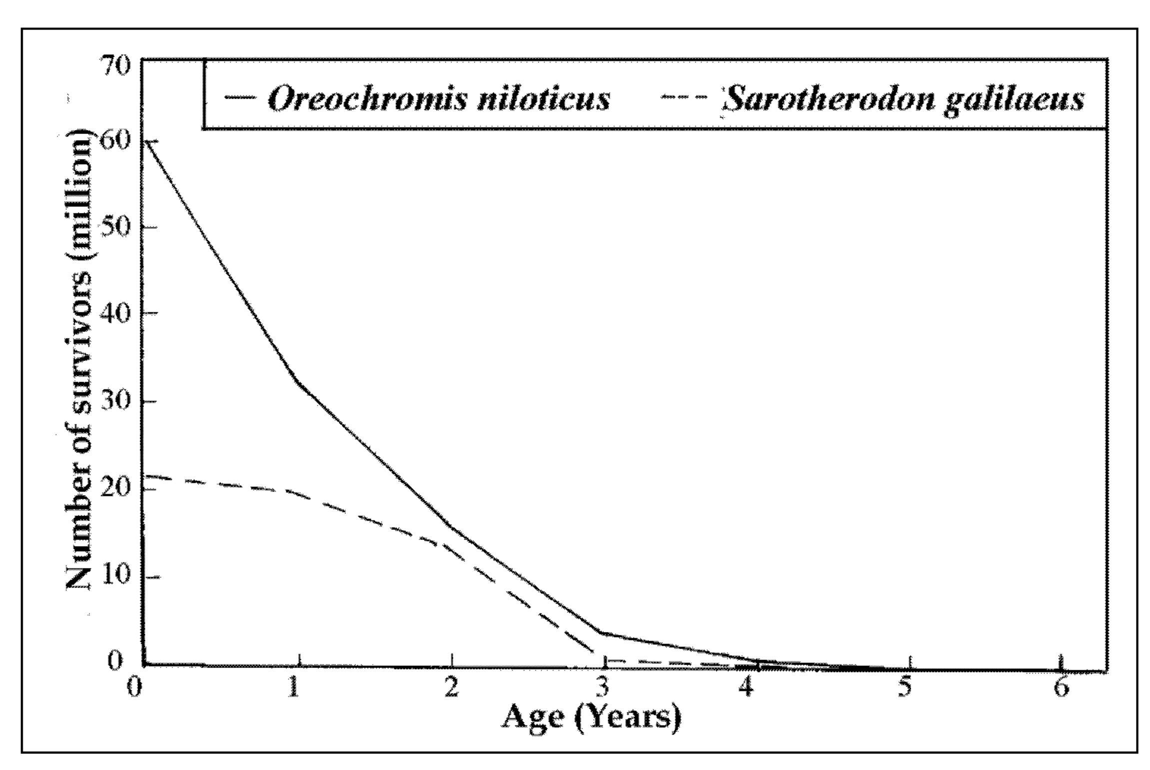


Fig. 185 **Survivorship curves of 1979-cohorts of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser (Mekkawy 1998).**

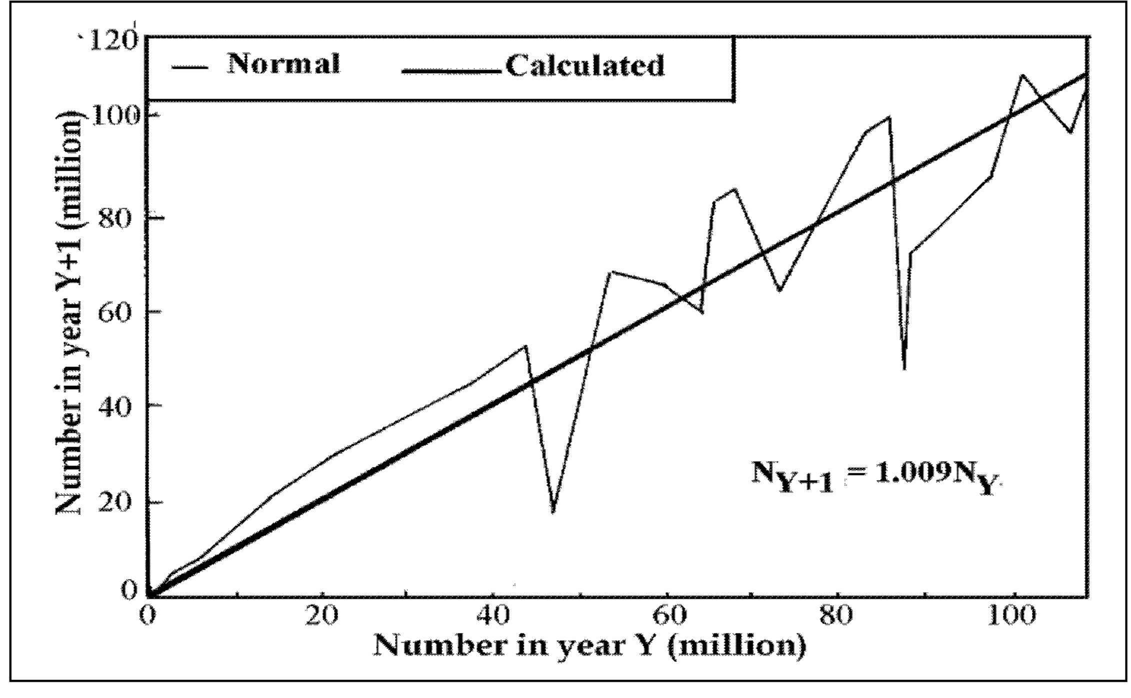


Fig. 186 **The relationship between the abundance of adult stock of *Oreochromis niloticus* in year Y and its abundance in year Y + 1 in 1966-1992 period (Mekkawy 1998).**

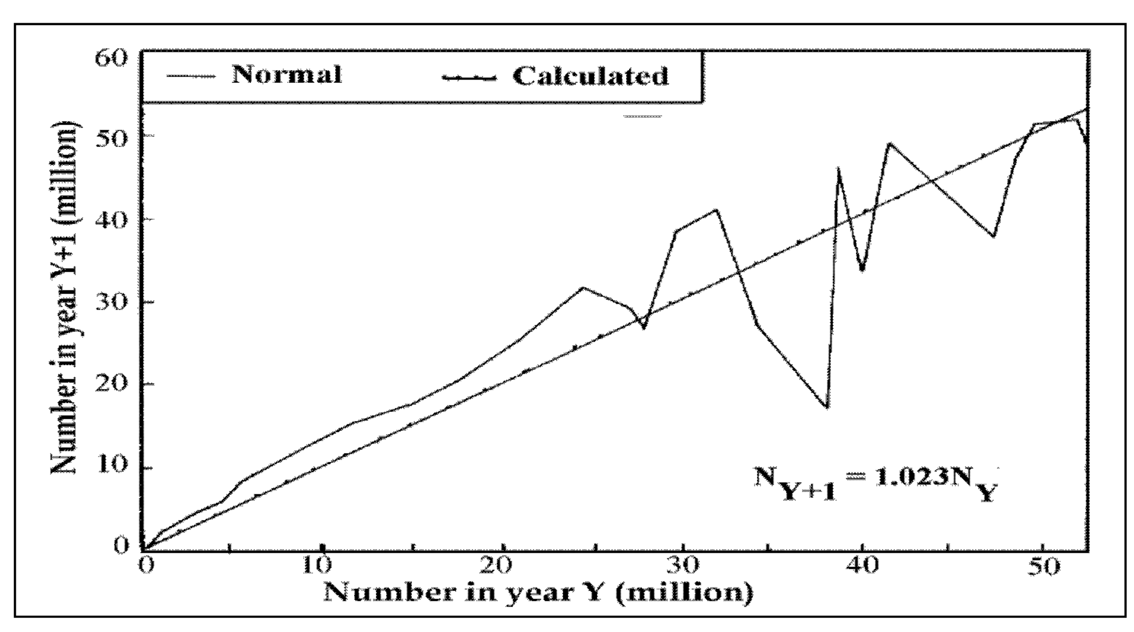


Fig. 187 **The relationship between the abundance of adult stock of *Sarotherodon galilaeus* in year Y and its abundance in year Y + 1 in 1966-1992 (Mekkawy 1998).**

CATCH PER UNIT EFFORT (CPUE)

In Lake Nasser, there are 91 carrier boats, which collect fishes caught by fishermen from the fishing grounds, and transport the catch to Aswan Harbour. The total catch from any fishing ground during one month may be divided by the number of fishing boats working in it, to get the value of CPUE (ton/boat/month). It is important to know the distribution of CPUE in order to exploit rationally fish resources in Lake Nasser. In addition, if one analyses the fluctuations of CPUE throughout the year, it may be possible to estimate the distribution of fish density and spawning grounds, and the relationship between fish distribution and environmental conditions. Accordingly, one can assign the number of fishing boats to each fishing ground.

The average CPUE in Lake Nasser during 1966-1999 was calculated and presented in Table 126. It is clear that the CPUE was less than one ton/boat/month during 1966-1977. Thus, it started at 0.31 ton/boat/month in 1966, and then gradually increased and reached 0.91 ton/boat/month in 1977 (Table 126). The CPUE fluctuated between about one and two ton/boat/month during 1978-1992. The maximum CPUE was 1.90 ton/boat/month and occurred in 1981 (Table 126). Then, the CPUE sharply decreased and was around 0.80 ton/boat/month during 1993-1996, and reached 0.64 ton/boat/month in 1999. It is worth mentioning that during the last 10 years, a part of the commercial catch is sold in the black market illegally at high prices. This leads to a drop in the calculated figures of the CPUE, during recent years.

Table 126 **Catch per unit effort (CPUE) (1966-1999).**

Year	Total fish catch (ton)	Number of fishing boats	Average CPUE (ton/boat/month)
1966	751	200	0.31
67	1415	350	0.34
68	2662	500	0.44
69	4670	599	0.65
1970	5676	816	0.58
71	6819	1039	0.55
72	8343	1135	0.61
73	10587	1440	0.61
74	12255	1540	0.66
75	14635	1630	0.75
76	15791	1680	0.78
77	18471	1690	0.91
78	22725	1700	1.11
79	27021	1613	1.40
1980	30216	1570	1.60
81	34206	1500	1.90
82	28667	1450	1.65
83	31282	1388	1.88
84	24534	1385	1.48
85	26450	1382	1.59
86	16315	1379	0.99
87	16815	1379	1.02
88	15888	1244	1.06
89	15650	1175	1.11
1990	21882	1915	0.95
91	30838	1927	1.33
92	26219	1961	1.11
93	17931	1900	0.79
94	22074	2200	0.80
95	22058	2200	0.84
96	20541	2200	0.78
97	20601	2200	0.78
98	19203	2200	0.73
1999	13983	2200	0.64

Regional and seasonal fluctuations of total catch and CPUE

For analysis of fish catch from the different areas, the northern and southern regions of the Lake are divided into fishing zones. Ecologically, these two regions of the Lake are considerably different from each other especially during the annual flood and or shortly afterwards. Only the southern part of the lake shows turbidity signs of flood.

As previously mentioned, the southern region of Lake Nasser showed higher mean annual values of chlorophyll "*a*" (about 12 mg/m^3) than the northern part (about 8-11 mg/m^3), and this may be due to the supply of sufficient nutrient salts from upper stream of the Nile to the southern part of the Lake (Mohamed, I. 1993a). Furthermore, Mohamed, I. (1993a) pointed out that the southern region of Lake Nasser is richer in zooplankton than the northern part.

Mohamed, M. (1993f) recorded the annual and monthly distribution of fish catch in each fishing ground from each region. The northern region was divided into 40 sectors (no. 1-40), while the southern region included 39 sectors (no. 41-79, Table 127, Figs, 188 a,b,c and d; 189 and 190).

Table 127 **Total monthly catch and CPUE (catch / boat / month) of the northern and southern regions of Lake Nasser (Mohamed, M. 1993f).**

Year	Fishing* ground (No.)	Total catch(kg)		CPUE (ton / boat / month)		No. of fishing boats	
		Aug.	Dec.	Aug.	Dec.	Aug.	Dec.
	1) 1-40	677767	587289	1.10	0.95	616	616
1988	2) 41-79	1031416	442279	1.64	0.70	+628	+628
	(2) / (1)	1.52	0.75	1.49	0.74	1244	1244
	1) 1 - 40	675892	610929	1.09	0.98	621	621
1989	2) 41 - 79	378288	526401	0.80	0.95	+473	+553
	(2)/(1)	0.56	0.86	0.73	0.97	1094	1174
	1) 1 - 40	1221319	1104181	1.13	1.03	1,070	1,070
1990	2) 41 - 79	1106638	1254249	1.31	1.48	+845	+845
	(2)/(1)	0.91	1.14	1.16	1.44	1915	1915
	1) 1 - 40	1480850	1346548	1.38	1.26	1,070	1,070
1991	2) 41 - 79	1963176	1813525	2.29	2.12	+857	+857
	(2)/(1)	1.33	1.35	1.66	1.68	1927	1927
	1) 1 - 40	847674	907116	0.79	0.85	1,070	1,070
1992	2) 41 - 79	1497936	1242001	1.68	1.41	+891	+880
	(2)/(1)	1.77	1.37	2.13	1.66	1961	1950

*** For fishing grounds refer to Fig. 188 a - d.**

The total fish catches of the northern and southern regions were compared during August and December 1988-1992, and the results (Table 127 - Mohamed, M. 1993f) indicate that there were no remarkable differences between the total catches during August and December in the same region. However, appreciable differences were recorded between the two regions, the highest fish yield was recorded in the southern region, compared to that from the northern region during the same period, except in 1989, when the reverse was true, and this may be attributed to the low number of fishing boats operating in the southern region.

The results show that the highest catches during five years (1988/92), were recorded in 15 fishing grounds in the Lake i.e. no. 4,11, 30, 31, 36, 38,42, 44, 50, 62, 67, 69, 70, 71 and 75 (Fig. 189). Most of the locations of fishing grounds with high catch were found in the southern region. While the

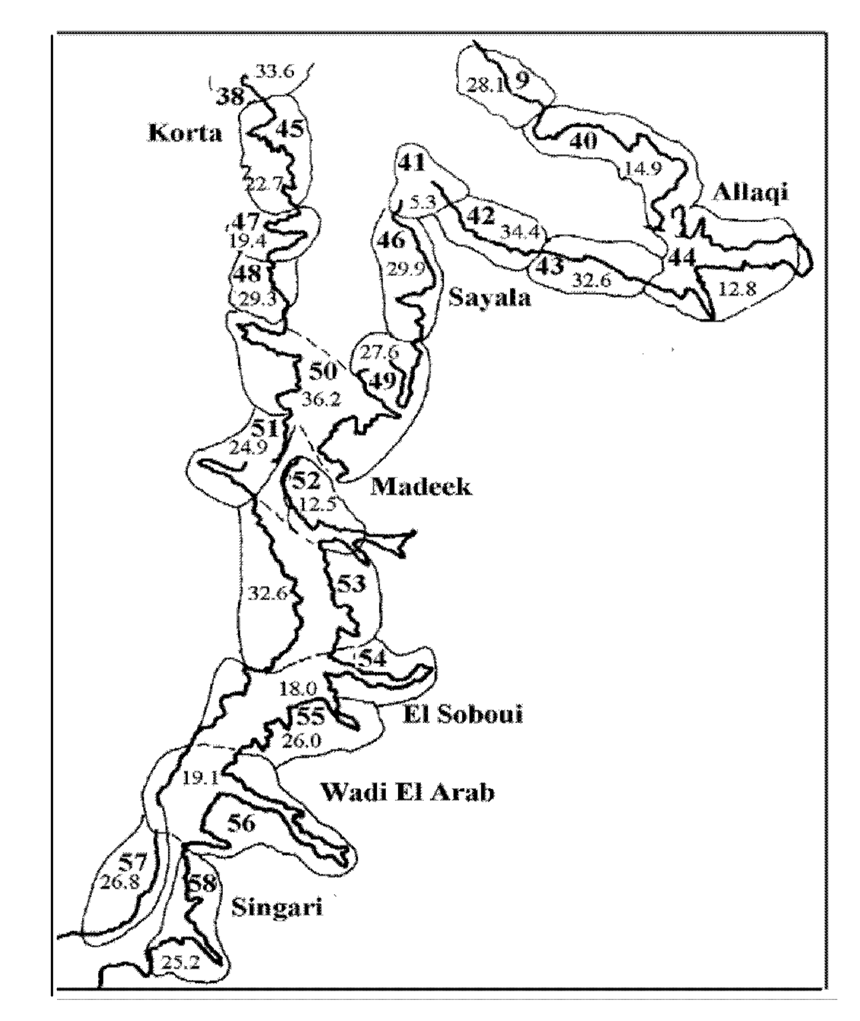


Fig. 188 a. **Mean value of total monthly catch (ton) from 1988 to 1992, fishing grounds no. 2-37 located in the northern region of Lake Nasser (Mohamed, M. 1993f).**

Fig. 188 b. **Mean value of total monthly catch (ton) from 1988 to 1992, fishing ground no. 38-58 located in the southern region of Lake Nasser (Mohamed, M. 1993f).**

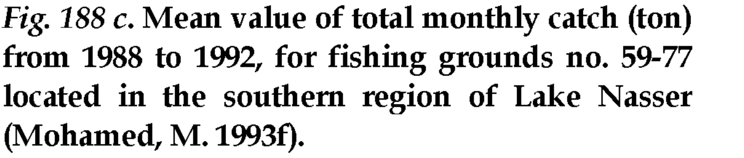


Fig. 188 c. **Mean value of total monthly catch (ton) from 1988 to 1992, for fishing grounds no. 59-77 located in the southern region of Lake Nasser (Mohamed, M. 1993f).**

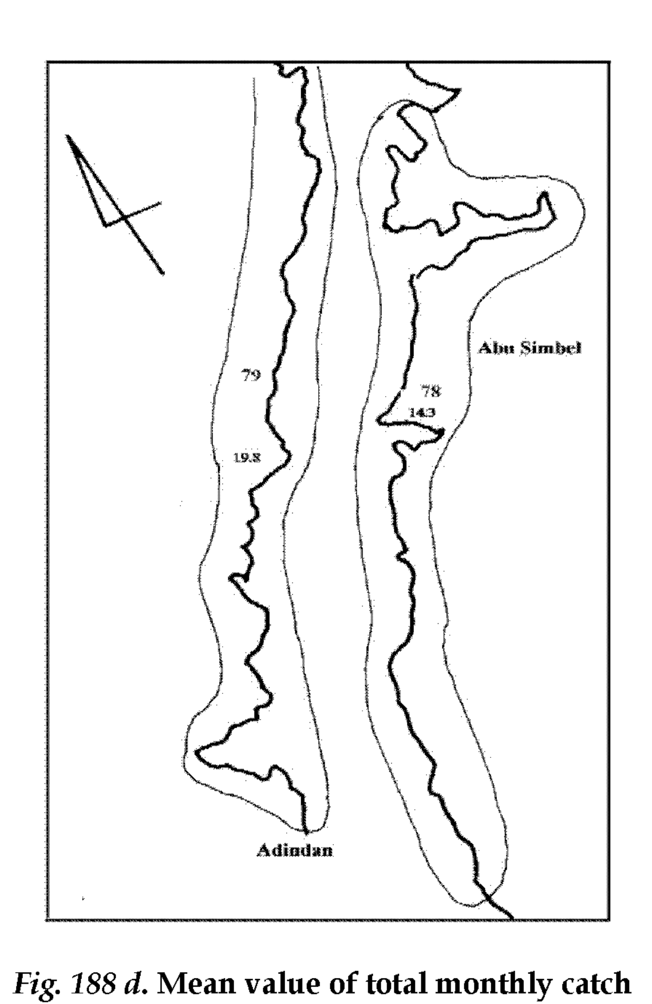


Fig. 188 d. **Mean value of total monthly catch (ton) from 1988 to 1992, for fishing grounds no. 78-79 located in the southern region of Lake Nasser (Mohamed, M. 1993f).**

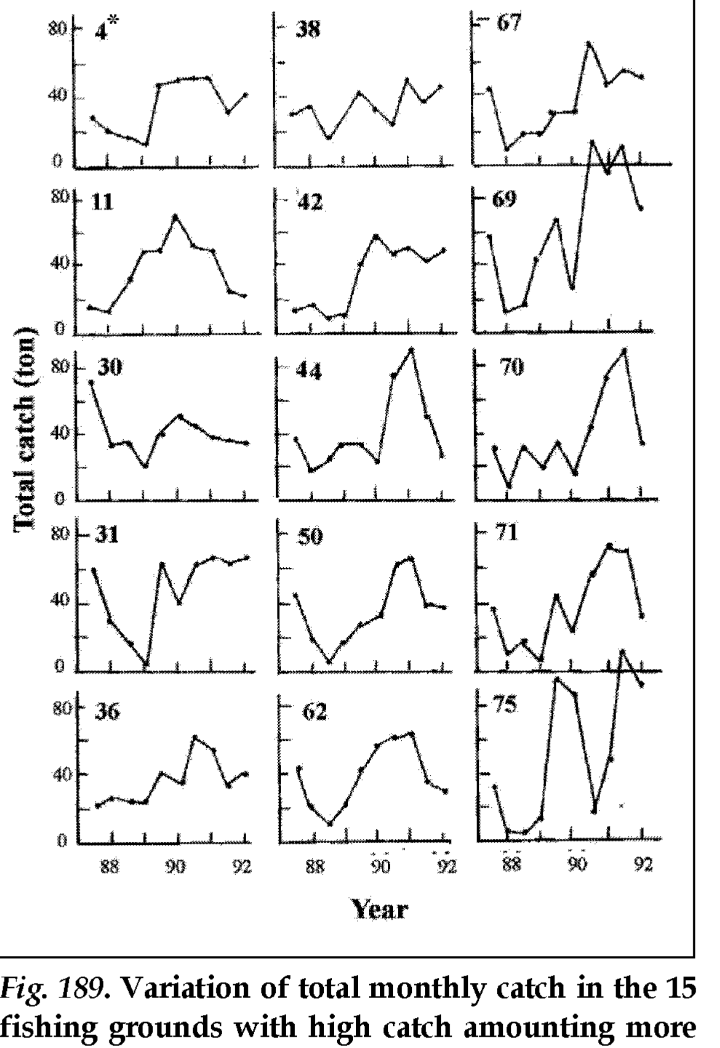


Fig. 189. **Variation of total monthly catch in the 15 fishing grounds with high catch amounting more than 335 and 833 kg from 1988 to 1992 (Mohamed, M. 1993f).** (*For fishing grounds refer to Fig. 188a-c).

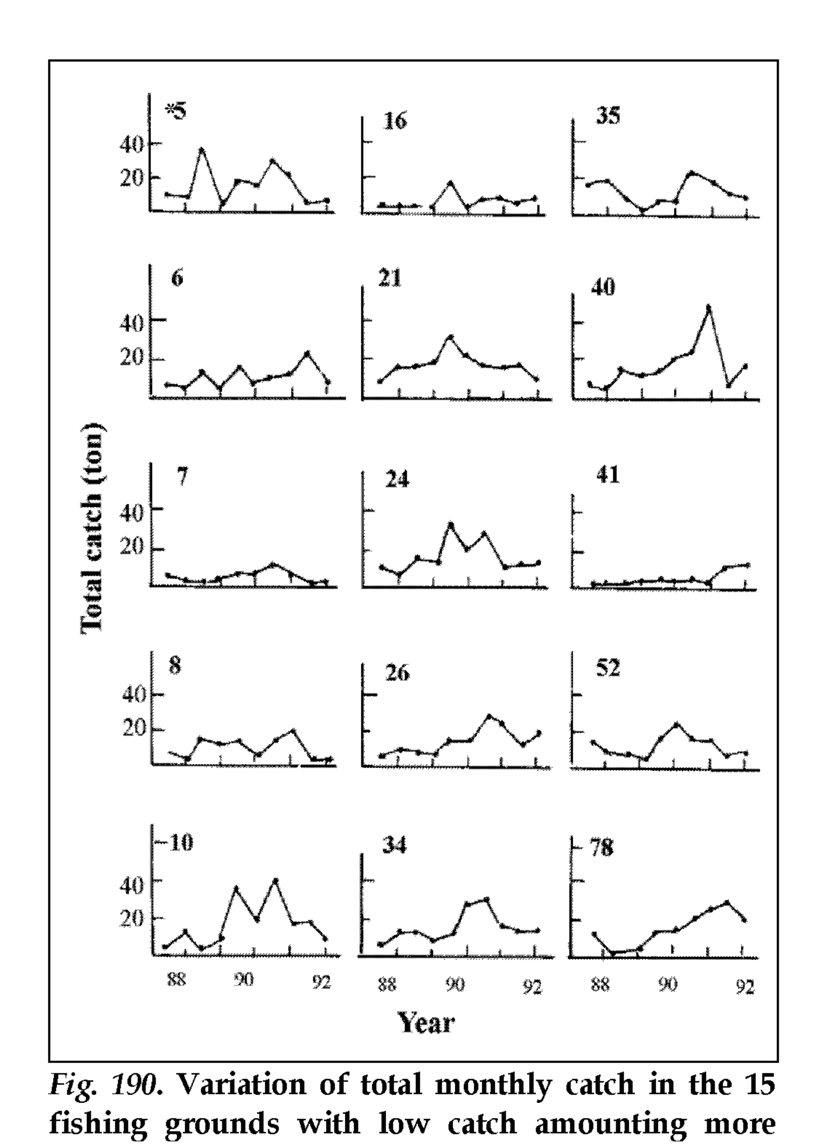


Fig. 190. **Variation of total monthly catch in the 15 fishing grounds with low catch amounting more than 179 and 225 kg from 1988 to 1992 (Mohamed, M. 1993f). (* For fishing grounds refer to Fig. 188a-d).**

lowest catches were collected from 15 fishing grounds, most of them are located in the northern region: no. 5, 6, 7, 8, 10, 16, 21, 24, 26, 34, 35, 40, 41, 52 and 78 (Fig. 190). This phenomenon suggests the possibility of developing active fisheries in the southern region of the Lake. High fish yields were collected from regions close to Allaqi, Korosko and Tushka (Mohamed, M. 1993e).

Adam (1992b) estimated CPUE in five widely separated areas of Lake Nasser, and therefore, it was difficult to get detailed information concerning the fishing grounds. Mohamed, M. (1993a) analysed CPUE of 79 fishing grounds during December, 1991. The location of each fishing ground is assigned a number starting from north to south. The latter author compared CPUE of the northern and southern fishing grounds, and obtained useful information on the exploitation of fishing resources, but the period was restricted only to one month (i.e. December, 1991). The results may be summerized as follows:

1. Total fish yield increases with increase of number of fishing boats.

2. CPUE decreases with the increase of the number of fishing boats, but the frequency distribution of CPUE was different between the northern and southern fishing grounds in the Lake.

3. The values of CPUE are higher in the southern fishing grounds than those in the northern grounds. This phenomenon shows high density of fishes in the southern fishing grounds.

In another investigation, Mohamed, M. (1993d) analysed CPUE and total catch of 79 fishing grounds during two months (August and December, 1991) in order to obtain information on the abundance of fish, actual condition of fishing and density of fishing boats. The results obtained by the latter author may be summerized as follows:

1. The mean value of total catch by fishing grounds of the southern region (i.e. 50.34 and 46.5 kg in August and December respectively) was 1.4 times that of the northern region (i.e. 37.02 and 33.66 kg) during the same month.

2. The mean value of CPUE in the southern region (i.e. 2.6 ton/boat/month) was 1.8 times higher than that of northern region (1.4 ton/boat/month). The density of fish mainly *Tilapia* species was high in the southern region of Lake Nasser.

In order to examine the value and distribution of CPUE (ton/boat/month) in each fishing ground of Lake Nasser Mohamed, M. (1993f) analysed the monthly catch of August and December from 1988 to 1992. The results indicate that the fishing grounds having high CPUE were found in the southern region of the Lake and were concentrated close to Allaqi, Korosko and Tushka (Tables 128 and 129). It is worth mentioning that the average value of

Table 128 **Mean value of CPUE (ton / boat / month) of the northern fishing grounds (No. 1-40).**

Fishing ground		Mean value of CPUE (ton / boat / month)			
No.	(Name)	(1988-1992) *	(1993)**	(1994)*** Spring	(1994)*** Summer
1	El Ramla	-	0.45	1.39	0.97
2	Dihmit (East)	1..24	1.44	1.46	0.64
3	Dihmit (East)	1.07	1.42	1.18	0.59
4	Dihmit (West)	1.15	0.75	1.30	0.40
5	Amberkab (East)	1.02	0.64	0.90	0.43
6	Amberkab (East)	0.92	0.56	1.00	0.46
7	Amberkab (West)	0.58	0.43	0.99	0.99
8	Amberkab (West)	0.95	0.53	1.00	0.47
9	Rahma (East)	1.34	0.78	0.96	0.43
10	Rahma (East)	1.34	0.77	0.69	0.68
11	Kalabsha	1.17	0.41	0.80	0.38
12	Gazal (North)	0.96	0.23	0.93	0.41
13	Gazal (North)	1.07	0.36	1.26	0.43
14	Gazal (North) inter	1.29	0.40	1.04	0.16
15	Gazal (North)	0.77	0.22	1.06	0.51
16	Gazal (Inter)	0.57	0.15	0.46	0.49
17	Kalabsha (South)	0.82	0.23	0.86	0.45
18	Gazal (South)	0.85	0.21	0.92	0.28
19	Merwaw (East)	1.46	0.57	1.05	0.66
20	Fallahin (West)	0.82	0.59	0.99	0.25
21	Merwaw (West)	1.16	0.44	1.02	0.62
22	Merwaw (West)	0.85	0.33	0.96	0.35
23	Merwaw (East)	0.91	0.56	1.00	0.32
24	Wadi Abyad (East)	0.71	0.40	0.81	0.26
25	Wadi Abyad (East)	1.11	0.75	0.71	0.15
26	Wadi Abyad	1.28	0.71	0.71	0.35
27	Wadi Abyad	1.25	0.78	0.66	0.43
28	Galal	1.17	0.36	1.31	0.44
29	Mariya	1.35	0.52	0.97	0.35
30	Garf Hussein (West)	1.20	0.54	0.86	0.51
31	Garf Hussein	0.91	0.47	0.62	0.17
32	Garf Hussein (West)	1.22	0.71	0.68	0.19
33	Gersha	1.93	1.28	0.73	0.58
34	Gersha (East)	1.46	0.58	0.63	0.09
35	Abesco (East)	1.15	0.74	1.43	0.22
36	Abesco (East)	1.65	0.76	1.13	0.18
37	Abu-Derwa (West)	1.31	0.59	0.77	0.45
38	Abu-Derwa (West)	1.01	0.55	0.68	0.12
39	Allaqi (North)	1.45	0.65	0.67	0.16
40	Allaqi (South)	0.99	0.53	1.05	0.12
Average		**1.11**	**0.59**	**0.94**	**0.48**

* Mohamed, M. (1993 f). ** Mohamed, M. (1995 a). *** Mohamed, M. (1995 b).

(For stations refer to Figs. 188 a and b).

Table 129 **Mean value of CPUE (ton / boat / month) of the southern fishing grounds (No. 41-79).**

Fishing ground		Mean value of CPUE (ton / boat / month)			
No.	(Name)	(1988 - 1992)*	(1993)**	(1994)***	
				Spring	Summer
41	Allaqi	1.24	0.98	0.57	0.37
42	Allaqi	2.77	1.61	1.20	0.46
43	Allaqi	1.77	1.05	0.77	0.36
44	Allaqi (East)	1.08	0.71	0.68	0.65
45	Korta (West)	1.06	0.67	1.07	0.30
46	Moharaka	1.04	0.89	1.93	0.71
47	Sayala (West)	1.97	0.79	1.07	0.36
48	Sayala (West)	1.00	0.61	0.37	0.31
49	Sayala (East)	1.24	0.81	0.53	0.41
50	Sayala (West)	1.55	0.72	0.44	0.30
51	Sayala (East - West)	2.16	1.24	0.86	0.27
52	Madiq (East)	1.07	0.93	0.83	0.46
53	Madiq (East - West)	1.05	0.95	1.35	0.49
54	El Soboui (East)	2.26	1.36	1.03	0.86
55	El Soboui (West - East)	1.26	1.04	1.34	0.86
56	Wadi El-Arab	1.02	0.58	1.39	0.70
57	Malki - Singary	1.36	0.67	0.53	0.30
58	Malki (East)	2.81	1.05	0.71	0.86
59	Korosko (East)	1.64	0.77	1.02	0.43
60	Korosko (Inter)	2.51	0.97	0.63	0.23
61	Korosko	3.25	1.73	0.87	0.35
62	Abu - Handal (East - West)	1.64	1.00	0.88	0.45
63	Abu - Handal (East - West)	1.27	0.59	0.88	0.40
64	Thomas - Afia	1.44	0.99	1.60	0.75
65	Ibrim - Afia	1.78	0.56	1.09	0.76
66	El Shebbak	1.81	0.97	0.90	0.49
67	Masmas (Inter)	1.69	1.22	0.72	0.40
68	Masmas (West)	1.34	0.85	1.29	0.78
69	Tushka (West)	1.78	1.03	1.44	1.44
70	Tushka (West)	1.81	1.75	2.08	0.98
71	Tushka (West)	1.91	1.80	1.62	1.28
72	Tushka (West)	1.48	0.86	2.24	1.13
73	Forgondy (West)	1.59	0.92	2.54	1.74
74	Forgondy (West)	1.10	0.72	1.56	1.11
75	Tushka (East)	1.18	1.04	1.90	1.21
76	Hamido (East)	1.50	1.36	1.91	1.15
77	Khor Bateakh	2.59	1.36	1.66	1.31
78	Abu Simbel (East)	0.74	0.33	0.86	0.47
79	Abu Simbel (West)	0.96	0.41	1.22	0.54
	Average	**1.61**	**0.97**	**1.17**	**0.69**

* Mohamed, M. (1993f) ** Mohamed, M. (1995 a) *** Mohamed, M . (1995 b). (For stations refer to Figs. 188 b and c).

CPUE in the southern region (i.e. 1.61 ton/boat/month) was about 1.45 times that of the northern region of the Lake (1.11 ton/boat/month) (Tables, 128 & 129). Mohamed, M. (1993f) selected 15 fishing grounds showing high values of CPUE and other 15 fishing grounds showing low values of CPUE and compared them in order to examine the variation of CPUE for five successive years (1988-1992). The results show that there are remarkable annual and monthly changes in the CPUE for fishing grounds where high catches were recorded especially during 1990 and 1991 (Figs. 191 & 192). On the other hand, the CPUE values did not change so much for the fishing grounds of low CPUE in 1990 and 1991. This may be attributed to location such as: close to khor inlet or on flat shoreline, or to bottom characters (sandy or rocky) and to other reasons.

When considering the relation between the mean value of CPUE and number of fishing grounds in the northern and southern regions of Lake Nasser, it seems that higher values of CPUE (more than 2 ton/boat/month) were recorded from the fishing grounds, located in the southern region of the Lake (Table 130). Thus, six fishing grounds having mean values of CPUE ranging from 2 to 3 ton/boat/month, and one fishing ground, having a mean value of CPUE more than 3 ton/boat/month were recorded in the southern region of the Lake (Table 130).

The fishing grounds no. 42, 58 and 61 have the highest CPUE (over 2.7 ton/boat/month) (Table 131). Nevertheless, their total yields (1988-1992) were 344, 252 and 267 ton respectively (Table 131). Therefore, it is difficult to evaluate the potential productivity of each fishing ground by the value of CPUE (Mohamed, M. 1993f). In order to compare the environmental conditions of the high and low CPUE fishing grounds, more elaborate studies should be carried out in future.

Mohamed, M. (1995 a) studied the distribution of CPUE in Lake Nasser in 1993 (Tables, 132 & 133, and Fig. 193 a - d) and found high values of CPUE in the southern areas of the Lake (Fig. 193 b-d). The mean value of CPUE in the fishing grounds from no. 1 to 40 (northern region of the Lake) was 0.59 ton / boat / month, while the mean value of CPUE from no. 41 to 79 (the southern region of the lake) was 0.97 ton / boat / month. The value of CPUE in the southern region reached 1.6 times that in the northern region of the Lake (Mohamed, M. 1995 a), thus confirming the previous findings (Mohamed, M. 1993d).

The monthly mean catch in 1993 was 526.8 ton in fishing grounds from no. 1 to 40, and the mean value per fishing ground was 13.2 ton. However, the monthly mean catch in 1993 from fishing grounds no. 41 to 79 in the southern region was 810.5 ton and the mean value per fishing ground was 20.8 ton. Thus, the total catch of the southern region reached 1.5 times that of the northern region of the Lake (Mohamed, M. 1995 a).

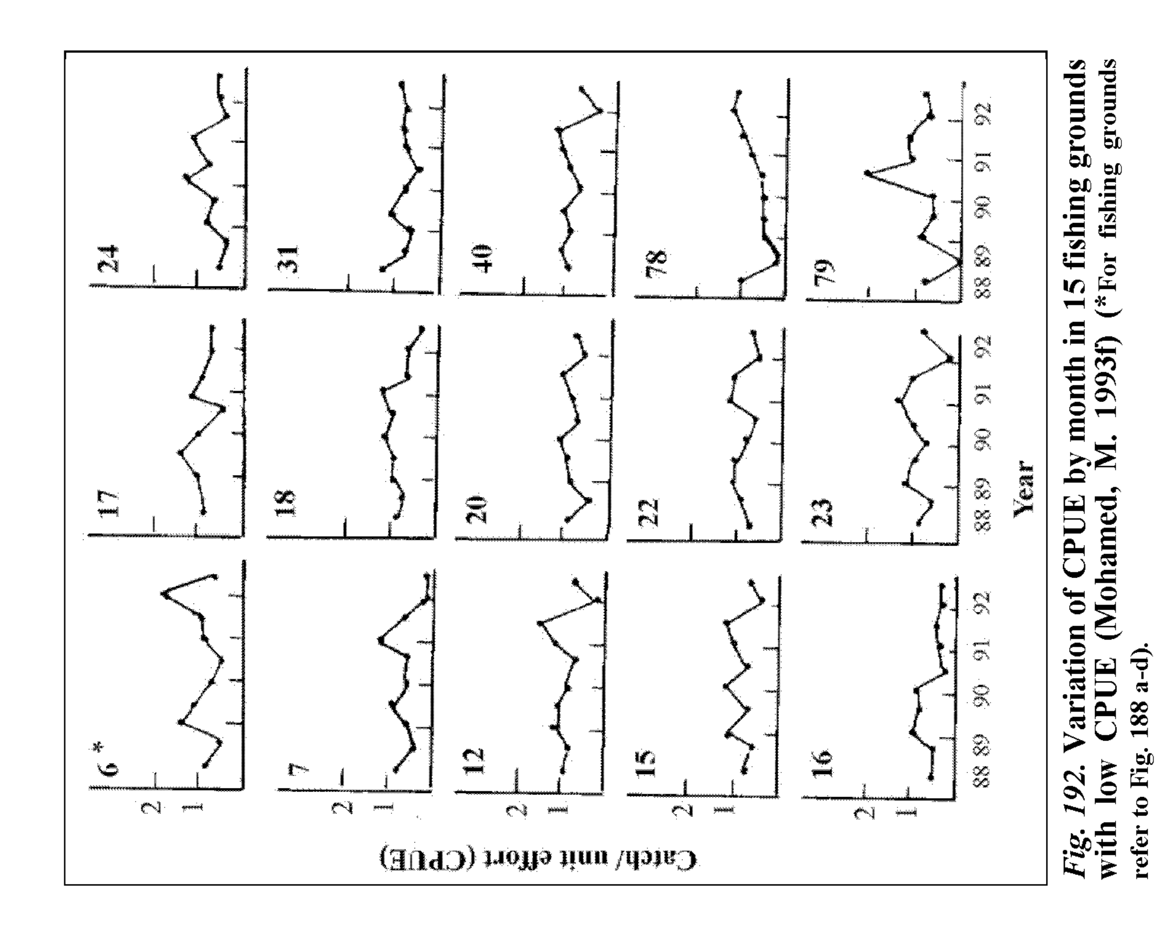


Fig. 192. **Variation of CPUE by month in 15 fishing grounds with low CPUE (Mohamed, M. 1993f)** (*For fishing grounds refer to Fig. 188 a-d).

Table 130 **Relation between mean value of CPUE and number of fishing**

Fig. 191 **Variation of CPUE by month in 15 fishing grounds with high CPUE (Mohamed, M. 1993f)** (*For fishing grounds refer to Fig. 188a-c).

Table 131 **Mean value of CPUE, total catch from 1988 to 1992 and number of**

fishing boats in 15 fishing grounds with high CPUE (Mohamed, M. 1993f) (For fishing grounds refer to Fig. 188 a-c).

Fishing ground No.	Mean value of CPUE (ton / boat / month)	Total catch-Aug. Dec. (1988 - 1992) (ton)	Number of fishing boats (Dec. 1992)
33	1.93	194.54	9
42	2.77	344.45	13
43	1.77	325.90	17
47	1.97	194.09	10
51	2.16	249.21	11
54	2.26	179.58	27
58	2.81	251.75	12
60	2.51	296.14	12
61	3.25	266.89	8
65	1.78	217.21	14
66	1.81	312.88	19
69	1.78	609.00	36
70	1.81	381.52	20
71	1.91	368.42	20
77	2.59	246.31	13

***Table* 132 CPUE, total catch, number of fishing boats and fishermen in the northern region of Lake Nasser in 1993 (monthly average). (Mohamed, M.1995a).**

Fishing ground		Capacity (ton)	No. of cruises	Total catch (kg)	No. of fishing boats	No. of fisher-men	No. of fishing camps	CPUE
No.	Name							
1	**El Ramla**		39	38.961	86	162	18	0.45
2	**Dihmit (East)**	77	3	14.608	10	21	5	1.44
3	**Dihmit (East)**	10	3	18.771	13	23	7	1.42
4	**Dihmit (West)**	10	4	23.853	31	62	10	0.75
5	**Amberkab (East)**	7	3	8.920	14	29	5	0.64
6	**Amberkab (East)**	7	3	8.912	16	32	5	0.56
7	**Amberkab (West)**	7	2	3.873	9	20	3	0.43
8	**Amberkab (West)**	7	3	7.449	14	27	4	0.53
9	**Rahma (East)**	20	5	26.460	34	65	9	0.78
10	**Rahma (East)**	10	6	13.922	18	45	3	0.77
11	**Kalabsha**	10	3	10.972	27	58	4	0.41
12	**Gazal (North)**	10	3	7.840	34	70	7	0.23
13	**Gazal (North)**	20	3	14.590	40	7	6	0.36
14	**Gazal (North) Inter**	20	3	12.124	30	61	8	0.40
15	**Gazal (North)**	20	4	8.248	37	75	9	0.22
16	**Gazal (Inter)**	7	2	3.492	20	38	5	0.15
17	**Kalabsha (south)**	20	3	9.211	39	79	7	0.23
18	**Gazal (South)**	20	4	7.993	38	72	10	0.21
19	**Merwaw (East)**	10	5	10.896	19	33	4	0.57
20	**Fallahin (West)**	10	2	14.278	24	52	7	0.59
21	**Merwaw (West)**	10	3	6.614	15	29	3	0.44
22	**Merwaw (West)**	10	41	9.433	26	50	6	0.33
23	**Merwaw (East)**	10	3	15.072	27	56	7	0.56
24	**Wadi Abyad (East)**	20	2	9.988	25	52	4	0.40
25	**Wadi Abyad (East)**	20	3	23.147	31	55	5	0.75
26	**Wadi Abyad**	20	3	9.868	14	27	3	0.71
27	**Wadi Abyad**	20	3	20.245	26	48	5	0.78

Table 132 **Cont.**

Fishing ground		Capacity (ton)	No. of cruises	Total catch (kg)	No. of fishing boats	No. of fisher-men	No. of fishing camps	CPUE
No.	Name							
28	**Galal**	20	1	6.495	18	35	4	0.36
29	**Mariya**	20	1	7.809	15	42	3	0.52
30	**Garf Hussein (West)**	20	1	6.536	12	26	4	0.54
31	**Garf Hussein**	30	1	19.670	39	89	8	0.47
32	**Garf Hussein (West)**	20	1	12.477	12	27	3	0.71
33	**Gersha**	20	2	11.504	9	18	1	1.28
34	**Gersha (East)**	20	2	8.751	15	45	4	0.58
35	**Abesco (East)**	10	2	9.591	13	40	6	0.74
36	**Abesco (East)**	20	2	19.072	23	47	8	0.76
37	**Abu-Derwa (West)**	20	1	4.109	24	48	8	0.59
38	**Abu-Derwa (West)**	20	1	13.585	25	53	7	0.55
39	**Allaqi (North)**	20	2	29.607	41	67	14	0.65
40	**Allaqi (South)**	20	2	10.807	20	61	7	0.53
	Total			**526.753**				**23.39**
	Mean			**13.169**				**0.59**

(For fishing grounds refer to Fig. 188 a and b).

Mohamed, M. (1995 b) compared the catch per unit effort and the total catch per month from Lake Nasser between spring and summer of 1994 (Tables, 134 and 135, and Figs. 194 and 195). The results may be summerized as follows:

1. During spring, there was no fishing ground having CPUE more than 2.0 ton/boat/month in the northern region of Lake Nasser; while in the southern region of the Lake three fishing grounds (no. 70, 72 and 73) had CPUE more than 2.0 ton / boat / month. Twenty four fishing grounds had CPUE less than 1.0 ton / boat / month in the northern region of the Lake, compared with only seventeen fishing grounds in the southern region. The mean value of CPUE by fishing grounds was 0.94 ton / boat / month in the northern region of the Lake, and 1.17 ton / boat / month in the southern region. Thus the mean value of CPUE in the southern region reached 1.3 times as much as that of the northern region (Tables 134 and 135).

Table 133 **CPUE (ton/boat/month), total catch, number of fishing boats and fishermen in the southern region of Lake Nasser in 1993 (monthly average) (Mohamed, M. 1995a).**

Fishing ground		Capacity	No. of	Total catch	No. of fishing	No. of fisher-	No. of fishing	CPUE
No.	**Name**	**(ton)**	**cruises**	**(kg)**	**boats**	**men**	**camps**	
41	**Allaqi**	10	2	6.668	7	22	2	0.98
42	**Allaqi**	20	3	30.547	19	57	2	1.61
43	**Allaqi**	20	1	18.160	13	43	5	1.05
44	**Allaqi (East)**	30	2	31.990	45	123	18	0.71
45	**Korta (West)**	20	2	16.099	24	70	7	0.67
46	**Moharrka**	30	3	27.541	31	90	15	0.89
47	**Sayala (West)**	20	1	7.910	10	22	2	0.79
48	**Sayala (West)**	20	3	23.889	39	78	7	0.61
49	**Sayala (West)**	20	1	16.825	21	57	11	0.81
50	**Sayala (West)**	20	2	20.209	27	72	10	0.72
51	**Sayala (East-West)**	20	3	13.656	11	30	4	1.24
52	**Madiq (East)**	20	1	13.929	15	48	3	0.93
53	**Madiq (East-West)**	30	2	26.575	28	84	9	0.95
54	**El Soboui (East)**	20	2	12.476	9	29	2	1.36
55	**El Soboui (East-West)**	30	3	22.757	22	91	12	1.04
56	**Wadi El Arab**	20	1	11.077	19	78	7	0.58
57	**Malki- Singary**	30	2	18.030	27	82	8	0.67
58	**Malki**	20	2	8.422	8	30	2	1.05
59	**Korosko (East)**	20	2	11.566	15	72	7	0.77

(For fishing grounds refer to Fig. 188 b and c).

Table 133 Cont.

No.	Name	Capacity (ton)	No. of cruises	Total catch (kg)	No. of fishing boats	No. of fisher-men	No. of fishing camps	CPUE
60	Korosko (Inter)	20	3	13.572	14	48	73	0.97
61	Korosko	20	2	20.785	12	30	3	1.73
62	Abu Handal (East - West)	30	3	36.905	37	98	18	1.00
63	Abu Handal (East - West)	20	2	18.702	26	86	14	0.59
64	Thomas, Afia (East - West)	20	2	23.890	24	85	77	0.99
65	Ebrim, Afia	20	1	10.578	14	44	4	0.56
66	El-Shebbak	30	1	20.461	19	66	11	0.97
67	Masmas (West)	30	2	27.985	23	92	2	1.22
68	Masmas (inter)	30	2	24.527	29	82	5	0.85
69	Tushka (West)	60	3	30.369	36	146	5	1.03
70	Tushka (West)	30	2	36.745	21	78	6	1.75
71	Tushka (West)	30	2	36.059	20	69	4	1.80
72	Tushka (West)	20	2	16.341	19	54	6	0.86
73	Forgondy (West)	20	2	18.450	20	68	8	0.92
74	Forgondy (West)	20	2	20.000	28	97	5	0.72
75	Hamido (East)	30	3	46.059	42	141	22	1.04
76	Hamido (East)	20	3	28.564	21	84	15	1.36
77	Khor Bateakh	20	3	19.202	14	34	3	1.36
78	Abu Simbel (East)	20	2	10.184	25	57	10	0.33
79	Abu Simbel (West)	20	2	13.004	39	112	13	0.41
	Total			**810.489**				**37.89**
	Mean			**20.782**				**0.97**

(For fishing grounds refer to Fig. 188 c and d).

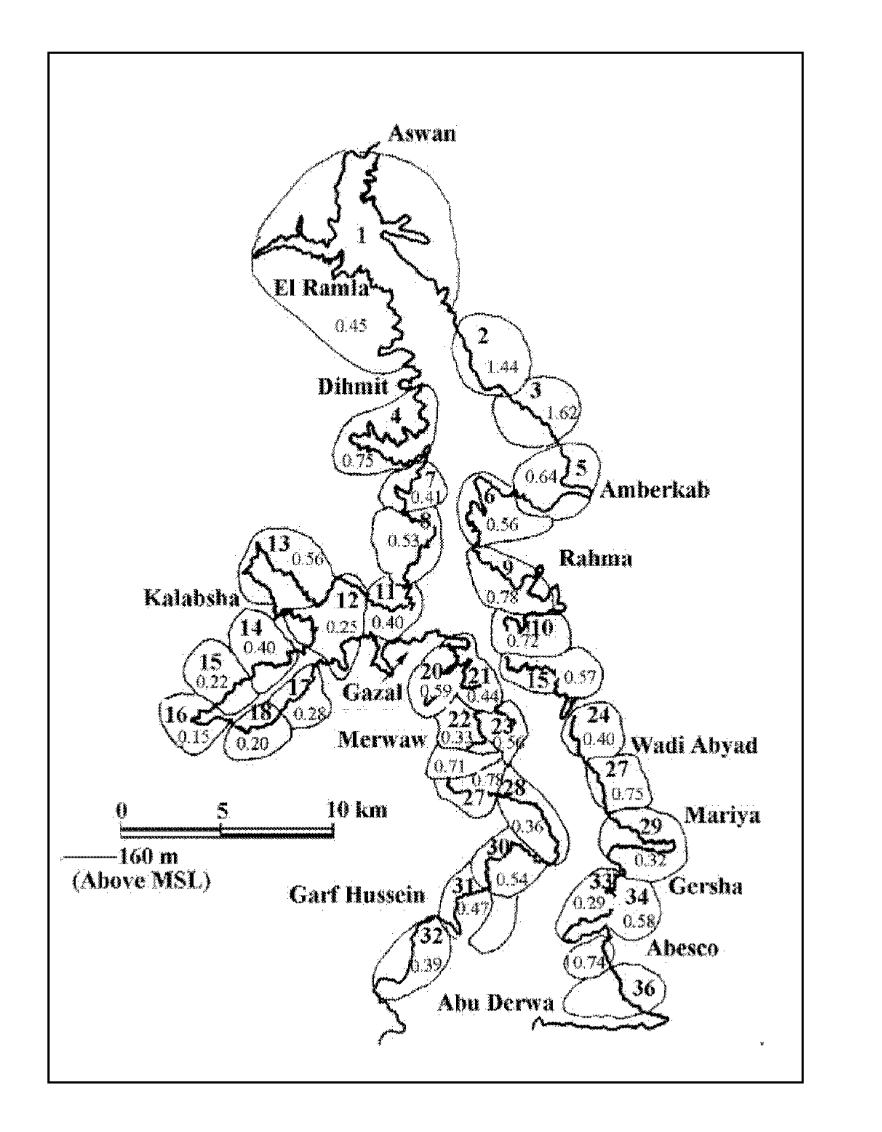


Fig. 193 a. **Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 1-37 (Mohamed, M. 1995a).**

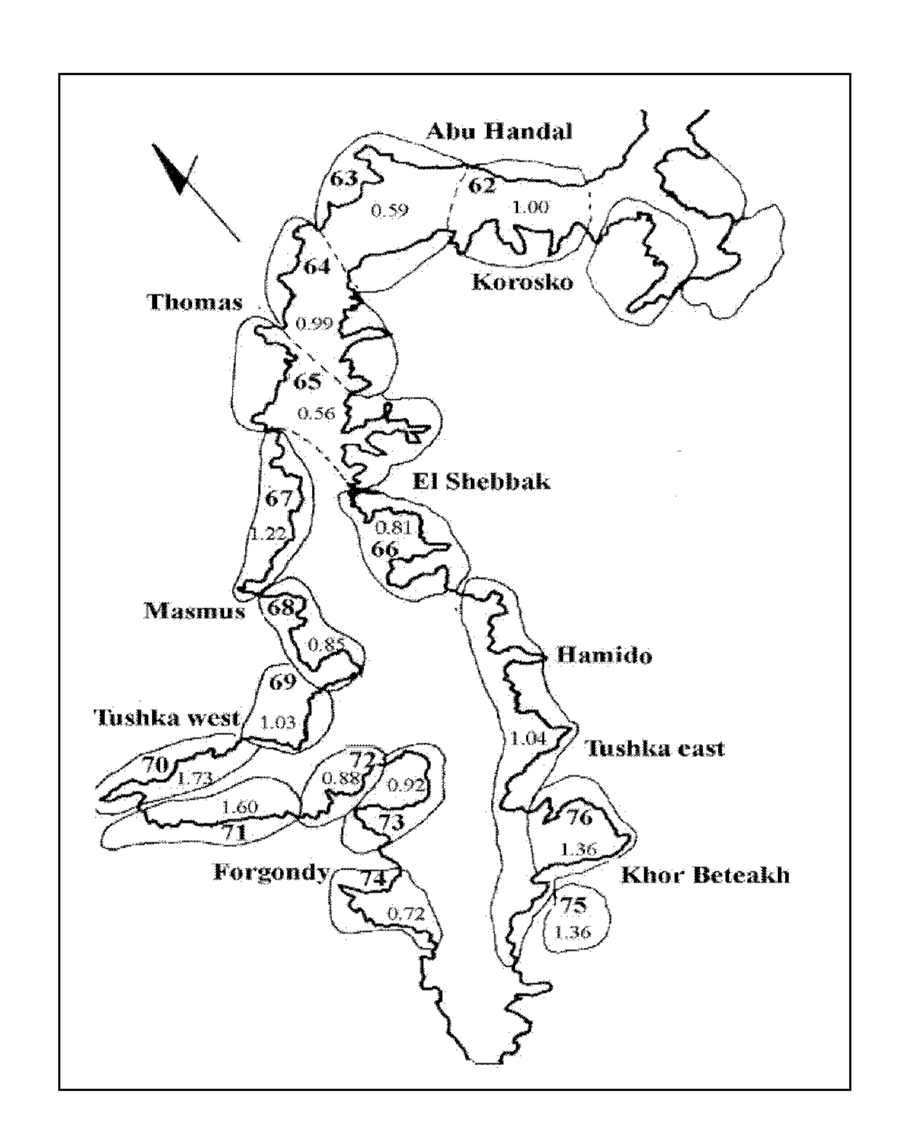


Fig. 193 b. **Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 38-58 (Mohamed, M. 1995a).**

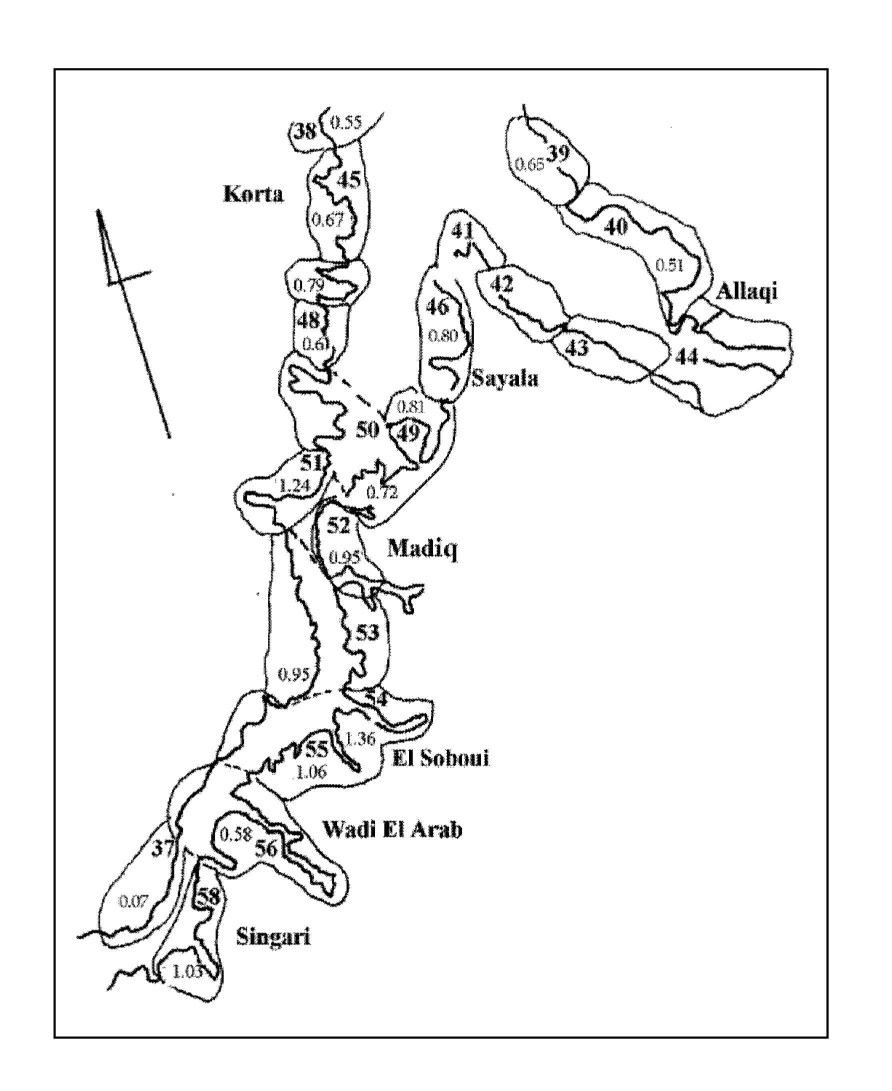


Fig. 193 c. **Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 59-77 (Mohamed, M. 1995a).**

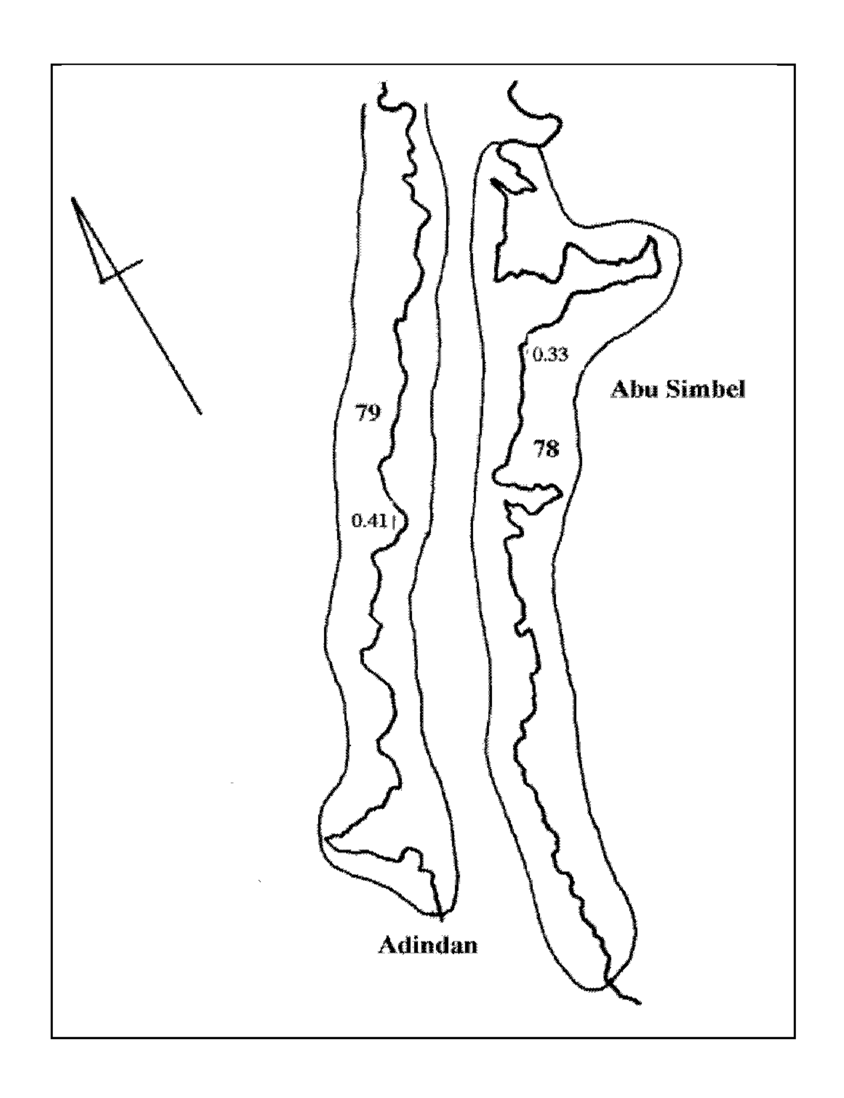


Fig. 193 d. **Distribution of CPUE (ton/boat/month) in Lake Nasser, fishing grounds no. 78 and 79 (Mohamed, M. 1995a).**

2. During summer, there was only one fishing ground having CPUE more than 1.0 ton / boat / month in the northern region of the lake, but in the southern region eight fishing grounds (no. 69, 71, 72, 73, 74, 75, 76 and 77) had CPUE more than 1.0 ton / boat/ month. The mean value of CPUE by fishing ground was 0.48 ton / boat / month in the northern region and 0.69 ton / boat / month in the southern region of the Lake. The mean value of CPUE in the southern region reached 1.4 times as much as that in the northern part of the Lake (Tables. 134 and 135).

Generally in 1994, the mean value of CPUE in spring was 1.05 ton / boat / month, but in summer it was 0.59 ton / boat / month. The mean value of CPUE in spring reached 1.8 times as high as that in summer . This phenomenon suggests that the density of fish, mainly *Tilapia* spp. was higher in spring than in summer. The frequency distribution of CPUE of 0.6 - 1.0 ton / boat / month was dominant in spring, but it was less than 0.5 ton / boat / month in summer.

The total catch per month by each fishing ground is represented in Tables 134 and 135 . In spring, fishing grounds having total catch per month more than 50 ton were no. 1 and 3 (in the northern region) and no. 62, 64, 69, 70, 71, 72, 73, 75, 76, and 77 (in the southern region). In summer, those having total catch per month more than 50 ton were no. 1 (in the northern region) and no. 69, 70, 71, 75 and 77 in the southern region. Only five fishing grounds had a total catch per month less than 10 ton in spring, but in summer there were 35 fishing grounds. The mean value of total catch per month by fishing ground in spring was 26.64 ton in the northern region and 40.96 ton in the southern region. Hence, the mean value in the southern region reached 1.5 times higher than that in the northern region of the Lake.

The mean value of total catch per month by fishing ground in summer was 10.36 ton in the northern region and 24.25 ton in the southern region. Hence, the mean value of the southern region reached 2.4 times that in the northern region. The total catch per month in spring was nearly twice that in summer in both northern and southern regions. The frequency of total catch per month of value 10.1 to 20 ton was dominant in spring but in summer it was less than 10 ton (Fig. 194).

When comparing the mean values of CPUE of the northern fishing grounds (no. 1-40) in two different periods (Table 128), we find that it was 1.11 ton / boat / month during 1988 - 1992 and 0.59 ton / boat / month during 1993. The same trend is observed in case of the southern fishing grounds (no. 41 - 79), as the average CPUE was 1.61 ton / boat / month during 1988 - 1992 and 0.97 ton/ boat / month in 1993 (Table 129). This means that there is a decrease in the average CPUE in the northern as well as the southern fishing grounds. However, it is obvious that, the southern fishing grounds are still higher in the density of fish than those of the northern fishing grounds (Tables 128 and 129).

Table 134 **Total catch per month and CPUE of the different fishing grounds in the northern region of Lake Nasser (spring and summer, 1994) (Mohamed, M. 1995 b).**

Fishing ground		Total catch (ton) per month		Number of fishing boats	CPUE (ton / boat / month)	
No	Name	Spring	Summer		Spring	Summer
1	El-Ramla	169.261	116.035	120	1.39	0.97
2	Dihmit (East)	27.801	12.116	19	1.46	0.64
3	Dihmit (East)	57.812	29.111	49	1.18	0.59
4	Dihmit (West)	23.308	7.230	18	1.30	0.40
5	Dihmit (East)	12.584	6.075	14	0.90	0.43
6	Amberkab (East)	13.030	6.002	13	1.00	0.46
7	Amberkab (West)	1.970	1.988	2	0.99	0.99
8	Amberkab (West)	9.991	4.717	10	1.00	0.47
9	Rahma (East)	30.610	13.661	32	0.96	0.43
10	Rahma (South)	2.059	2.050	3	0.69	0.68
11	Kalabsha	18.381	8.688	23	0.80	0.38
12	Gazal (North)	13.992	6.102	15	0.93	0.41
13	Gazal (West)	16.323	5.565	13	1.26	0.43
14	Gazal (North)	29.052	4.380	28	1.04	0.16
15	Gazal (North)	11.659	5.573	11	1.06	0.51
16	Gazal (Inter)	4.171	4.380	9	0.46	0.49
17	Kalabsha (South)	14.648	7.685	17	0.86	0.45
18	Gazal (South)	17.499	5.400	19	0.92	0.28
19	Merwaw (East)	25.227	15.815	24	1.05	0.66
20	Fallahin (West)	17.865	4.408	18	0.99	0.25
21	Merwaw (West)	7.150	4.350	7	1.02	0.62
22	Merwaw (South)	14.405	5.255	15	0.96	0.35
23	Merwaw (West)	20.077	6.321	20	1.00	0.32
24	Wadi Abyad (East)	23.467	7.590	29	0.81	0.26
25	Wadi Abyad (East)	18.378	4.011	26	0.71	0.15
26	Wadi Abyad	19.855	9.820	28	0.71	0.35
27	Wadi Abyad	19.150	12.473	29	0.66	0.43
28	Galal	32.828	11.028	25	1.31	0.44
29	Mariya	23.272	8.973	24	0.97	0.35
30	Garf Hussein (East)	24.799	14.731	29	0.86	0.51
31	Garf Hussein	18.045	4.930	29	0.62	0.17
32	Gersha	19.789	5.400	29	0.68	0.19
33	Gersha (East)	20.403	16.138	28	0.73	0.58
34	Abesco (East)	18.850	2.765	30	0.63	0.09
35	Abesco	41.588	6.250	29	1.43	0.22
36	Abu-Derwa (West)	36.080	5.680	32	1.13	0.18
37	Allaqi (North)	23.075	13.575	30	0.77	0.45
38	Allaqi (South)	19.080	3.335	28	0.68	0.12
39	Allaqi	20.907	4.935	31	0.67	0.16
40	Allaqi	27.280	5.540	26	1.05	1.12
Total		**1065.675**	**414.564**	**981**	**37.64**	**19.90**
Mean		**26.642**	**10.364**		**0.94**	**0.48**

(For fishing grounds refer to Fig. 188 a and b).

Table 135 **Total catch per month and CPUE of the different fishing grounds in the southern region of Lake Nasser (spring and summer, 1994) (Mohamed, M. 1995 b).**

Fishing ground		Total catch (ton) per month		Number of fishing boats	CPUE (ton / boat / month)	
No	Name	Spring	Summer		Spring	Summer
41	Allaqi	17.148	11.180	30	0.57	0.37
42	Allaqi	28.712	15.237	24	1.20	0.46
43	Allaqi	18.830	15.207	24	0.77	0.36
44	Allaqi (East)	19.058	18.315	28	0.68	0.65
45	Korta (West)	30.002	8.390	28	1.07	0.30
46	Moharaka	17.337	6.390	9	1.93	0.71
47	Sayala (West)	33.049	11.112	31	1.07	0.36
48	Sayala (West)	13.433	11.257	26	0.37	0.31
49	Sayala (East)	18.941	14.660	26	0.53	0.41
50	Sayala (West)	15.980	10.702	26	0.44	0.30
51	Sayala (East - West)	21.410	6.745	25	0.86	0.27
52	Madiq (East)	20.710	11.418	25	0.83	0.46
53	Madiq (East - West)	49.880	18.085	37	1.35	0.49
54	El Soboui (East)	23.60	19.768	23	1.03	0.86
55	El Soboui (West - East)	20.031	12.823	15	1.34	0.86
56	Wadi El-Arab	44.383	22.430	32	1.39	0.70
57	Malki - Singary	15.942	8.880	30	0.53	0.30
58	Malki (East)	19.880	24.255	28	0.71	0.86
59	Korosko (East)	48.759	20.620	48	1.02	0.43
60	Korosko (Inter)	13.754	5.050	22	0.63	0.23
61	Korosko	48.807	19.800	56	0.87	0.35
62	Abu - Handal (East - West)	57.150	29.295	65	0.88	0.45
63	Abu - Handal (East - West)	31.660	14.502	36	0.88	0.40
64	Thomas - Afia	86.620	40.378	54	1.60	0.75
65	Ibrim - Afia	38.165	26.707	35	1.09	0.76
66	Shebbak	45.895	25.010	51	0.90	0.49
67	Masmas (Inter)	25.847	14.555	36	0.72	0.40
68	Masmas (West)	37.353	22.525	29	1.29	0.78
69	Tushka (West)	51.671	51.760	36	1.44	1.44
70	Tushka (West)	116.397	54.734	56	2.08	0.98
71	Tushka (West)	84.179	66.749	52	1.62	1.28
72	Tushka (West)	62.638	31.665	28	2.24	1.13
73	Forgondy (West)	50.834	34.820	20	2.54	1.74
74	Forgondy (West)	29.724	21.068	19	1.56	1.11
75	Tushka (East)	104.256	66.728	55	1.90	1.21
76	Hamido (East)	70.563	42.692	37	1.91	1.15
77	Khor Bateakh	101.140	79.637	61	1.66	1.31
78	Abu Simbel (East)	21.545	11.706	25	0.86	0.47
79	Abu Simbel (West)	42.615	18.925	35	1.22	0.54
Total		**1597.239**	**945.774**	**1323**	**45.59**	**26.89**
Mean		**40.955**	**24.251**		**1.17**	**0.69**

(For fishing grounds refer to Fig. 188 b - d).

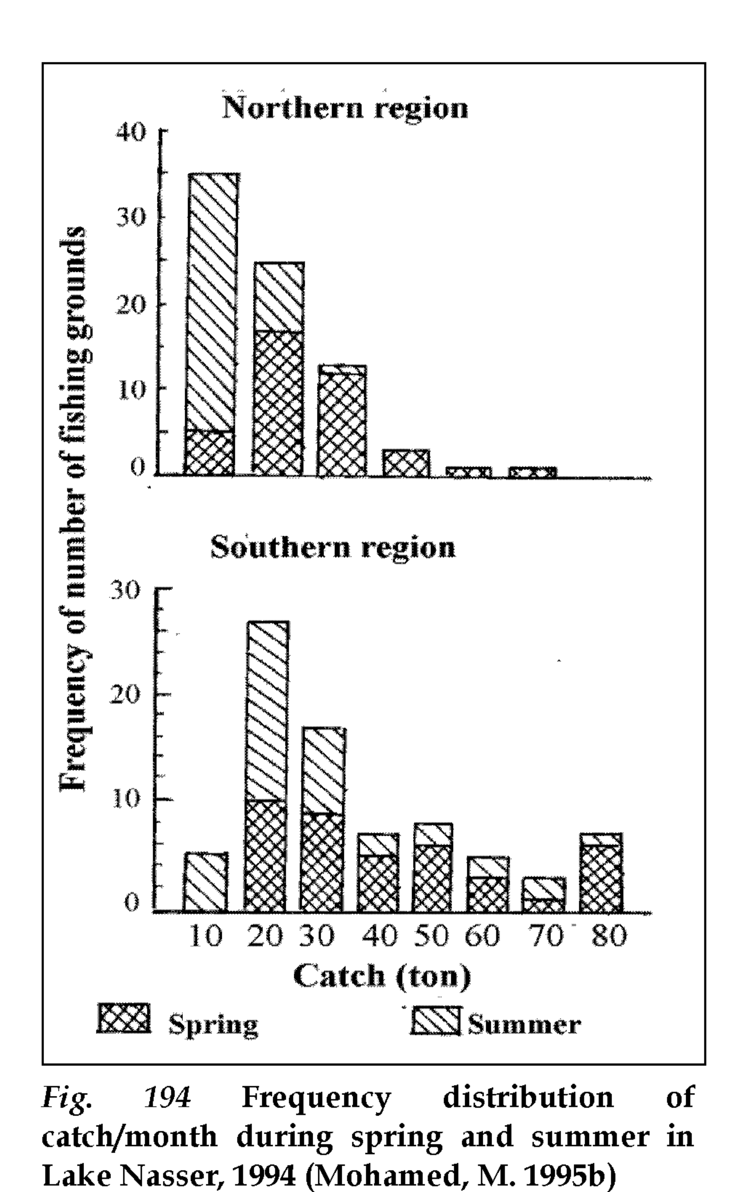


Fig. 194 **Frequency distribution of catch/month during spring and summer in Lake Nasser, 1994 (Mohamed, M. 1995b)**

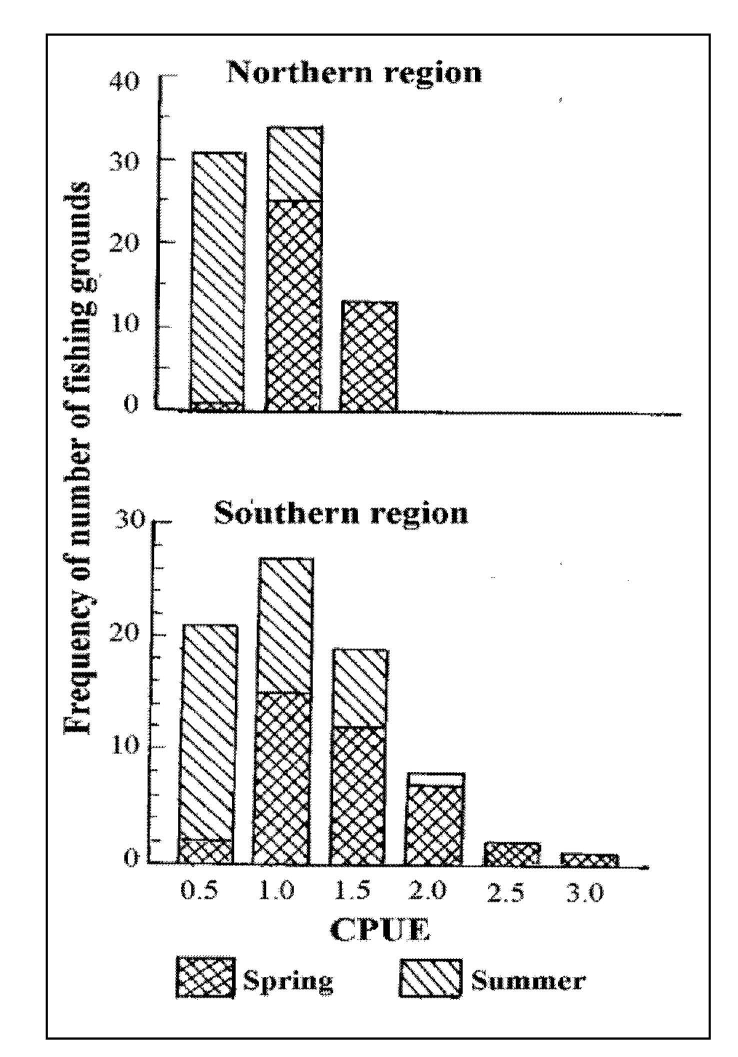


Fig. 195 **Frequency distribution of CPUE during spring and summer in Lake Nasser, 1994 (Mohamed, M. 1995b)**

Comparing the mean values of CPUE during 1994 in spring with those in summer in the northern fishing grounds, we find that the mean CPUE in spring was 0.94 ton / boat / month, and 0.48 ton / boat / month in summer (Table 136). The same trend was observed in the southern fishing grounds, as it was 1.17 in spring and 0.69 ton / boat / month in summer (Table 136). This means that the mean CPUE was higher in spring than that in summer in Lake Nasser. But, the mean CPUE is still higher in the southern fishing grounds during 1994.

***Table 136.* A comparison between the total catch/month (ton) and CPUE (ton/boat/month) of the northern and southern regions of Lake Nasser during spring and summer 1994.**

	1994	
	Spring	**Summer**
Northern region		
Total catch/month (ton)	1065.68	414.56
Mean (ton)	26.64	10.36
CPUE (ton/boat/month)	0.94	0.48
Southern region		
Total catch/month (ton)	1597.24	945.77
Mean (ton)	40.96	24.25
CPUE (ton/boat/month)	1.17	0.69

Relationship between CPUE of the total catch and of fish species catch of Lake Nasser and water level

Fig. 196 shows the relationships between catch per unit effort of the total catch and that of *Tilapia* spp. catch and water level (WL1 - WL6 : one to six years previous to the catch) of Lake Nasser during 1972 - 1992 (Mekkawy 1996). The latter author recorded the relationships between the catch per unit effort of *Lates niloticus, Hydrocynus, Labeo, Bagrus* and *Clarias* spp. and water levels (WL1 to WL6) of Lake Nasser during the same period 1972 - 1992 (Figs. 197 and 198). The simple correlation coefficients between fish species catch of Lake Nasser and water levels of the six preceding years and number of boats and that of fishermen is previously mentioned (page 314 - Table 112).

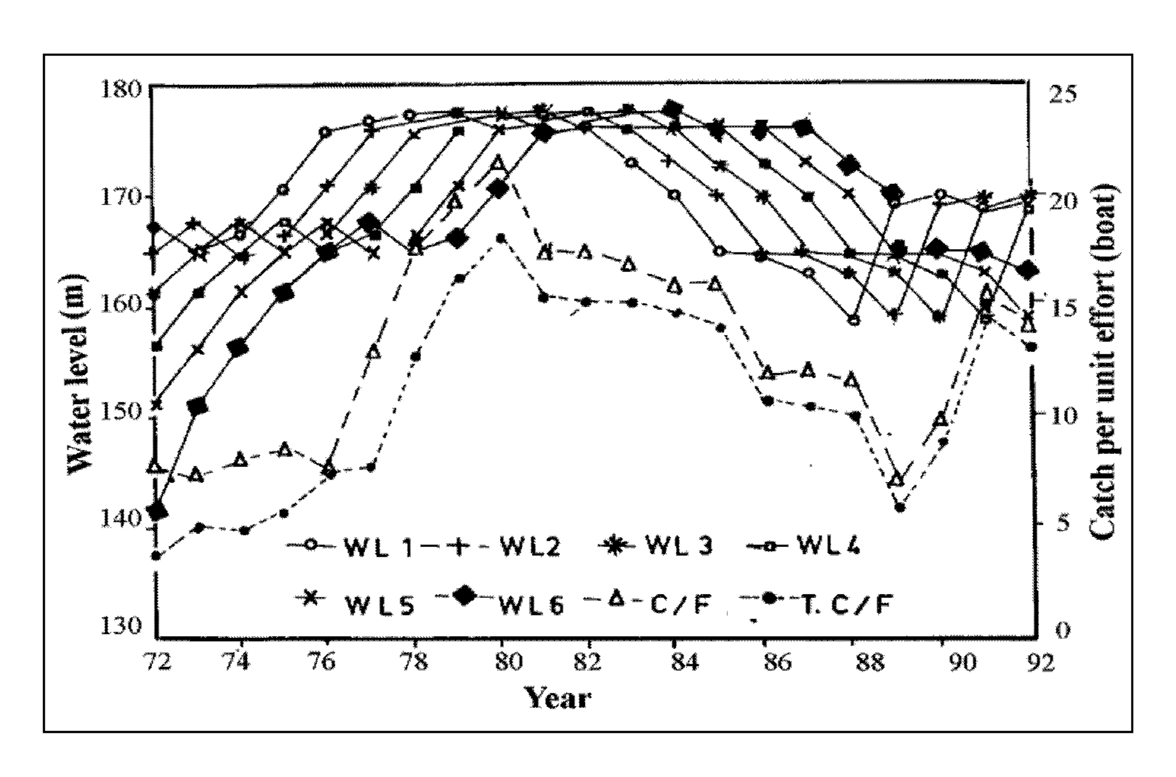


Fig. 196 The relationship between catch per unit effort of the total catch (C/F) and of *Tilapia* spp. catch (T.C/F) and water levels (WL1 - WL6) of Lake Nasser during 1972 - 1992 (Mekkawy 1996).

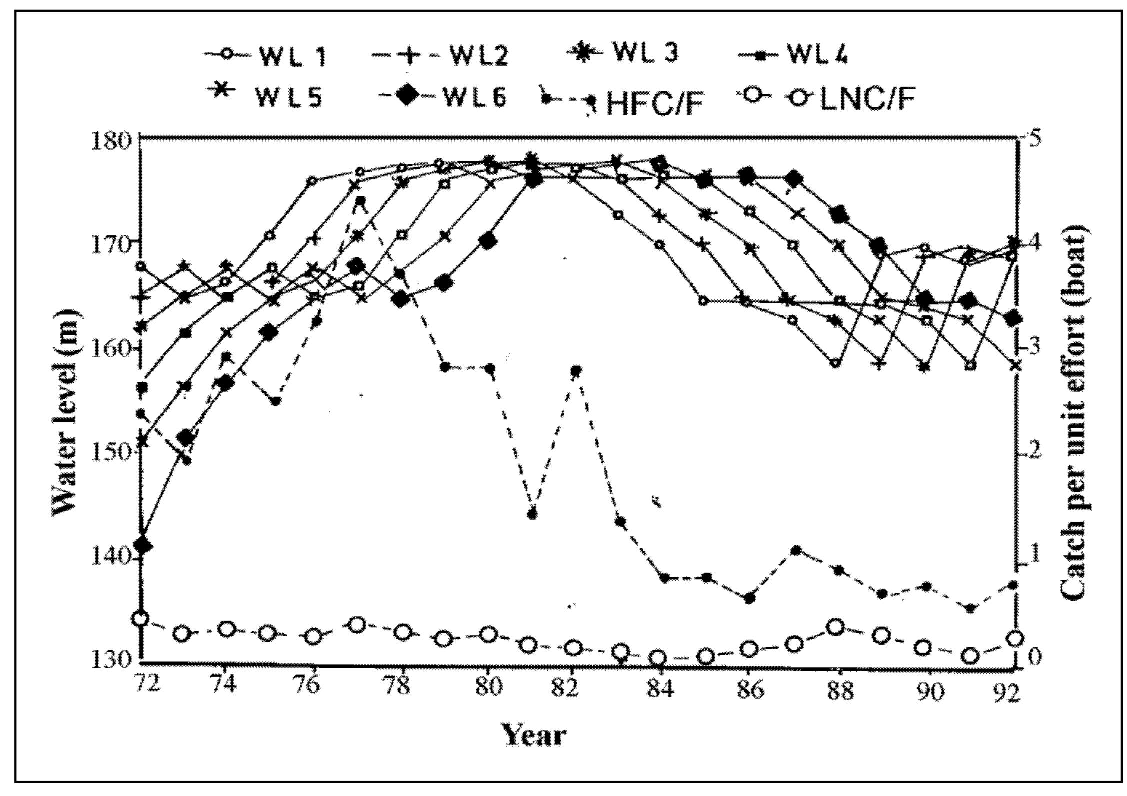


Fig. 197 The relationship between the catch per unit effort of *Hydrocynus* spp. (HFC/F)and *Lates niloticus* (LC/F) and water level (WL1 - WL6) of Lake Nasser in 1972-1992. (Mekkawy 1996).

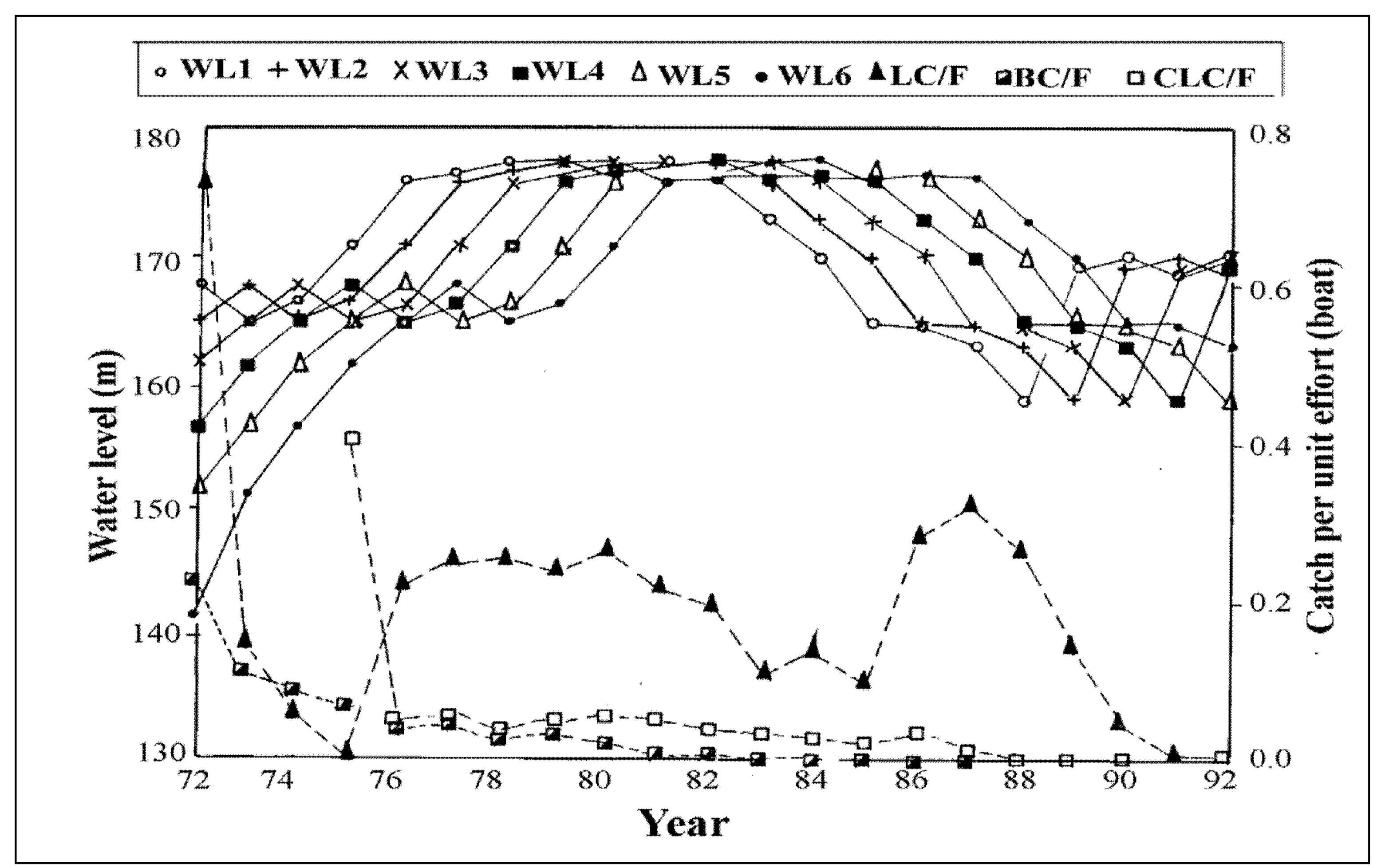


Fig. 198 **The relationship between the catch per unit effort of** ***Labeo*** **spp. (LC/F),** ***Bagrus*** **spp. (BC/F) and** ***Clarias*** **spp. (CLC/F) and water level (WL1 - WL6) of Lake Nasser in 1972-1992. (Mekkawy 1996).**

Relationships between CPUE and effort

The CPUE-effort relationships of *O. niloticus* and S. *galilaeus* (Fig. 201) indicate that the general trends of the relationships with respect to total catch and tilapiine catch were directed towards increase with time throughout 1966-1992. However, excluding the increased CPUE data of the initial years of Lake formation (1966-1972), CPUE decreased with the increased effort (Figs. 200 and 201). Mekkawy (1996) mentioned that the CPUE-effort relationships of *Hydrocynus* spp., *Lates niloticus, Labeo* spp. *Bagrus* spp., and *Clarias* spp. showed decreased trends in spite of the variable fluctuation throughout 1966-1992 (Figs 202 - 206). These trends were due to the continuous decline in their catch, thus no catch of *Bagrus* and *Clarias* spp. was recorded in recent years.

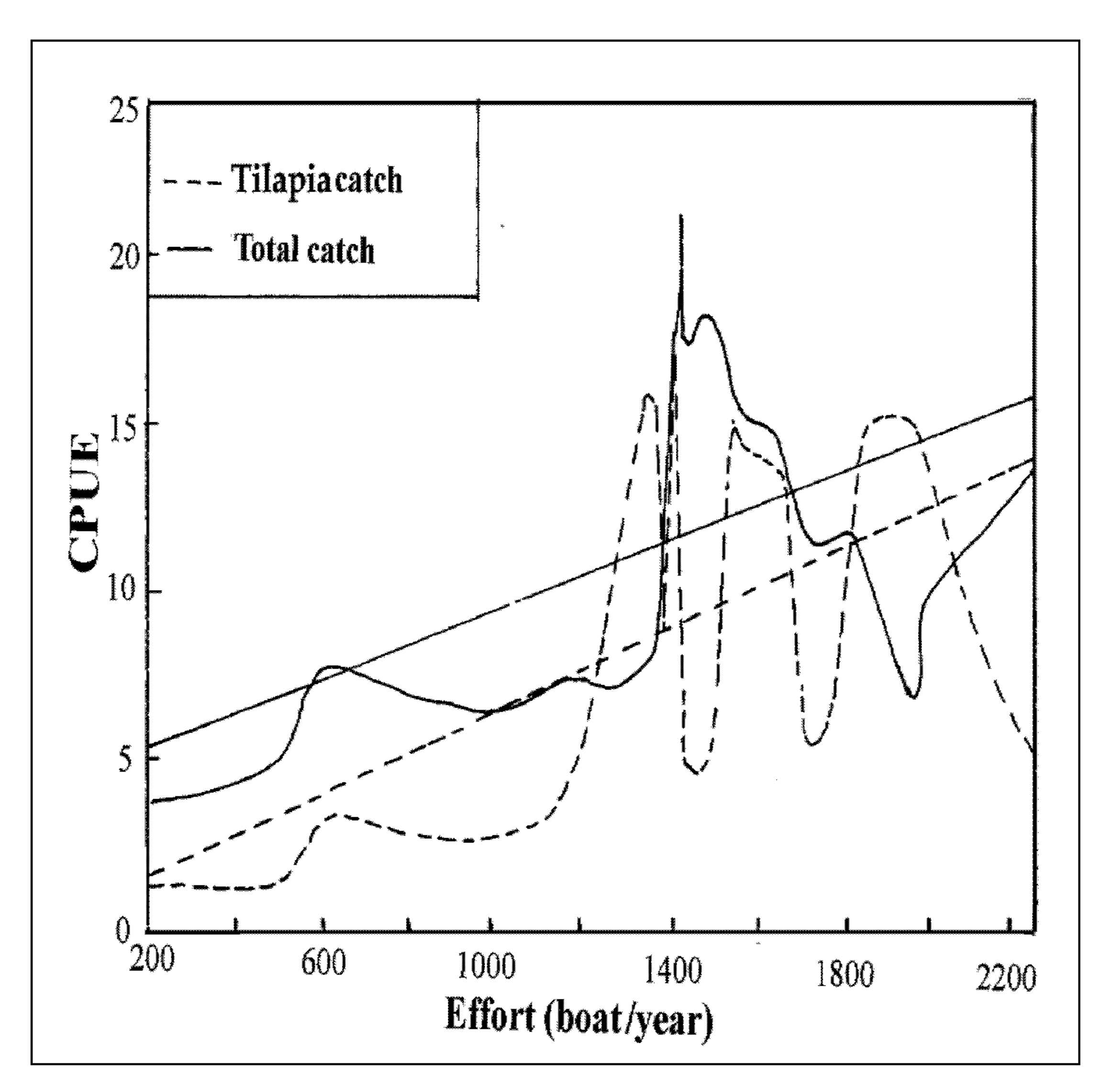


Fig. 199 **CPUE-effort relationship of total catch and *Tilapia* spp. catch of Lake Nasser (1966-1992) (Mekkawy 1996).**

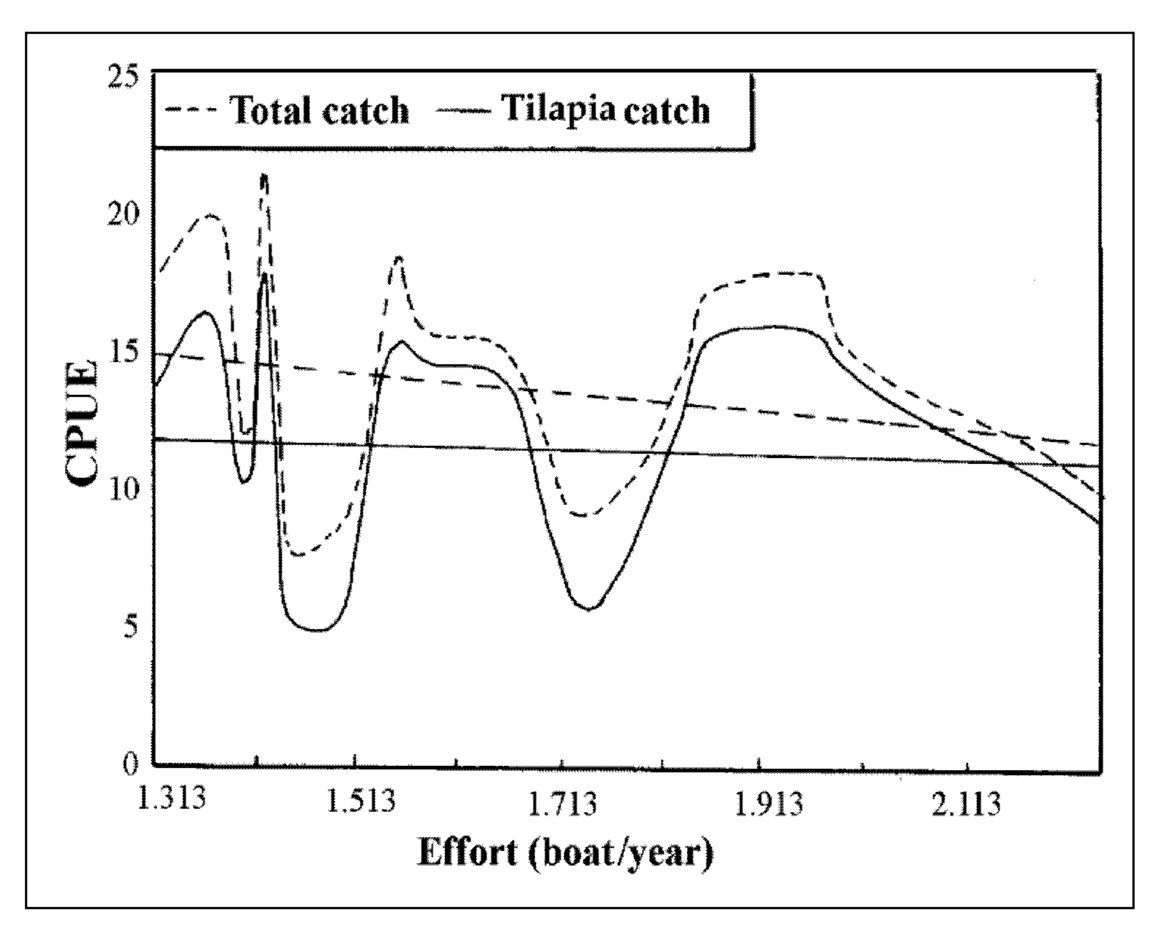


Fig. 200 CPUE-effort relationship of total catch and *Tilapia* spp. catch (1973-1992) (Mekkawy 1996).

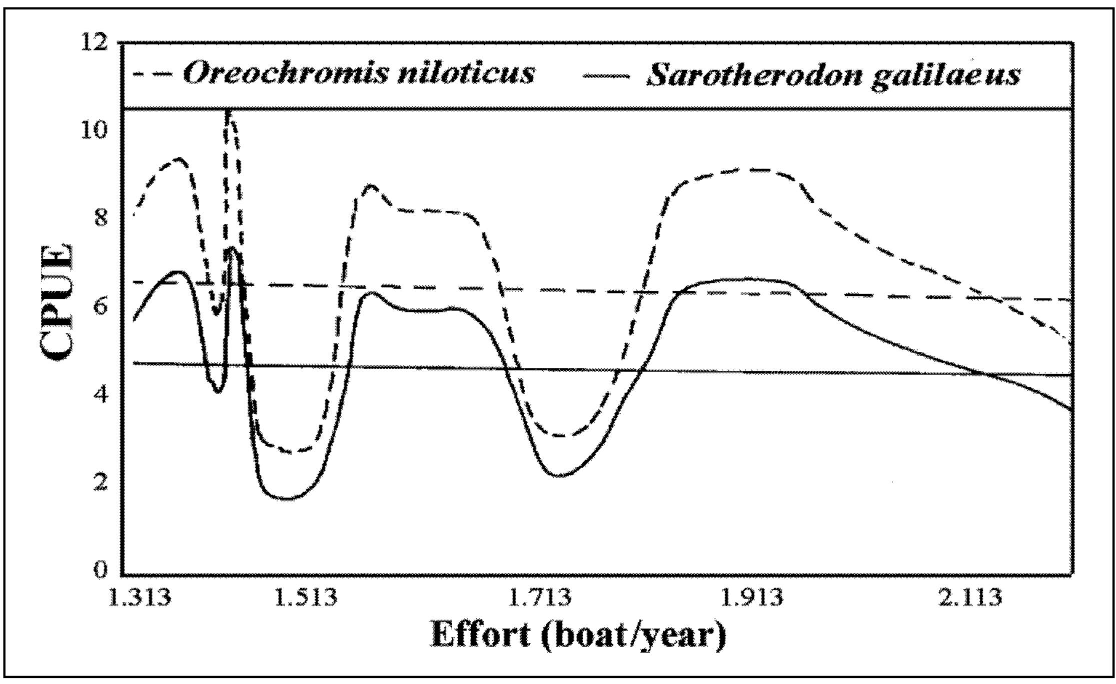


Fig. 201 CPUE-effort relationship of *Oreochromis niloticus* and *Sarotherodon galilaeus* (1973-1992) (Mekkawy 1996).

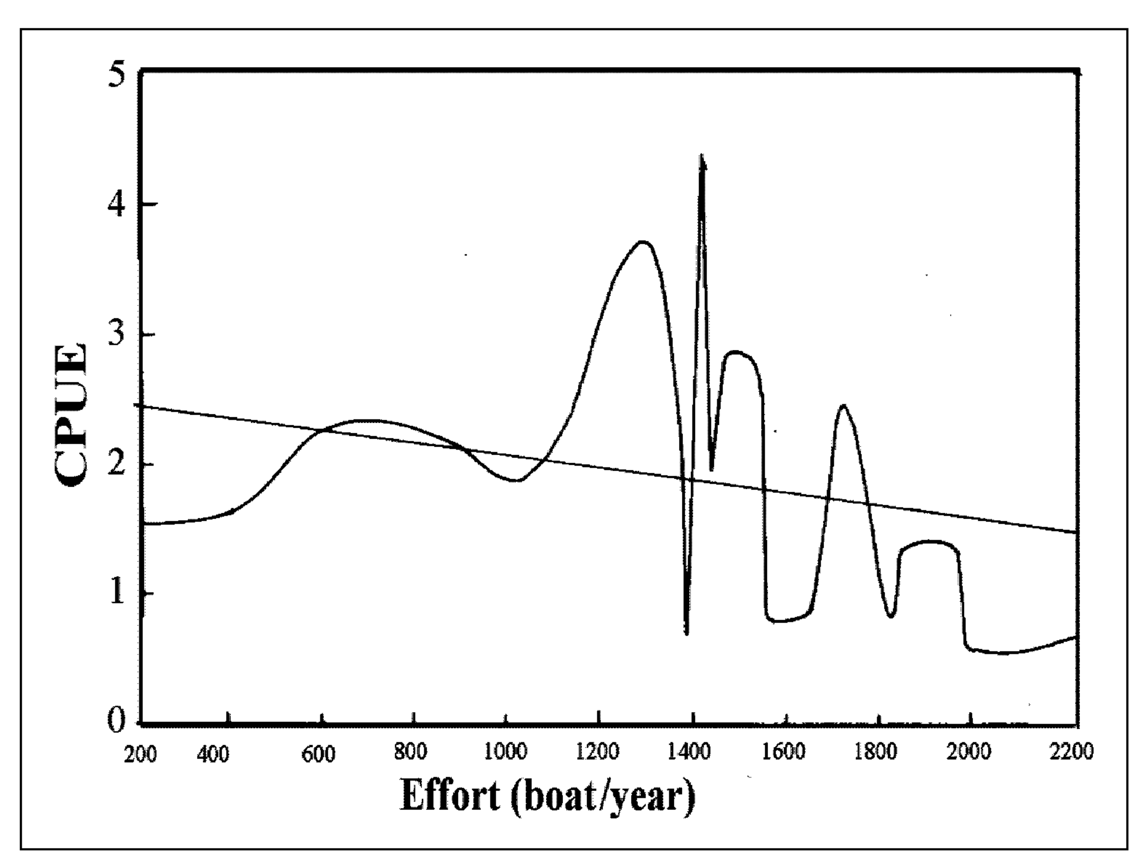


Fig. 202 CPUE-effort relationship of *Hydrocynus* spp. of Lake Nasser (1966-1992) (Mekkawy 1996).

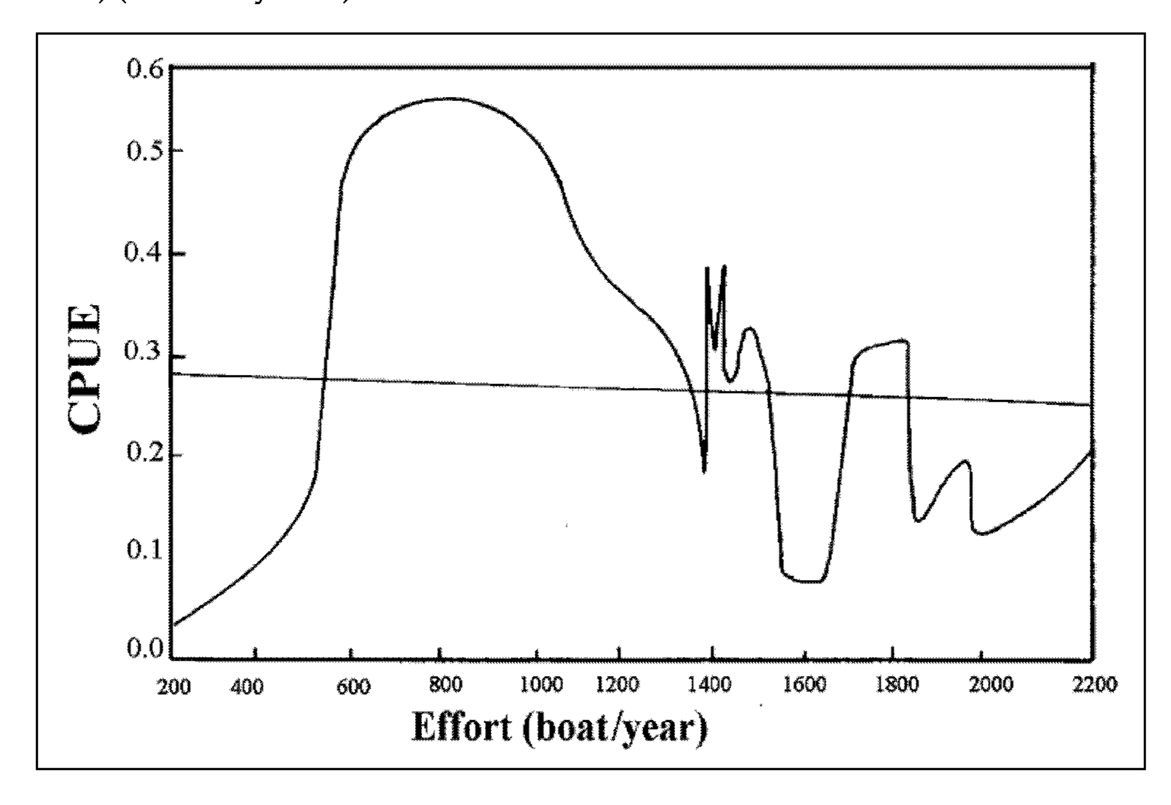


Fig. 203 CPUE-effort relationships of *Lates niloticus* (1966-1992) (Mekkawy 1996).

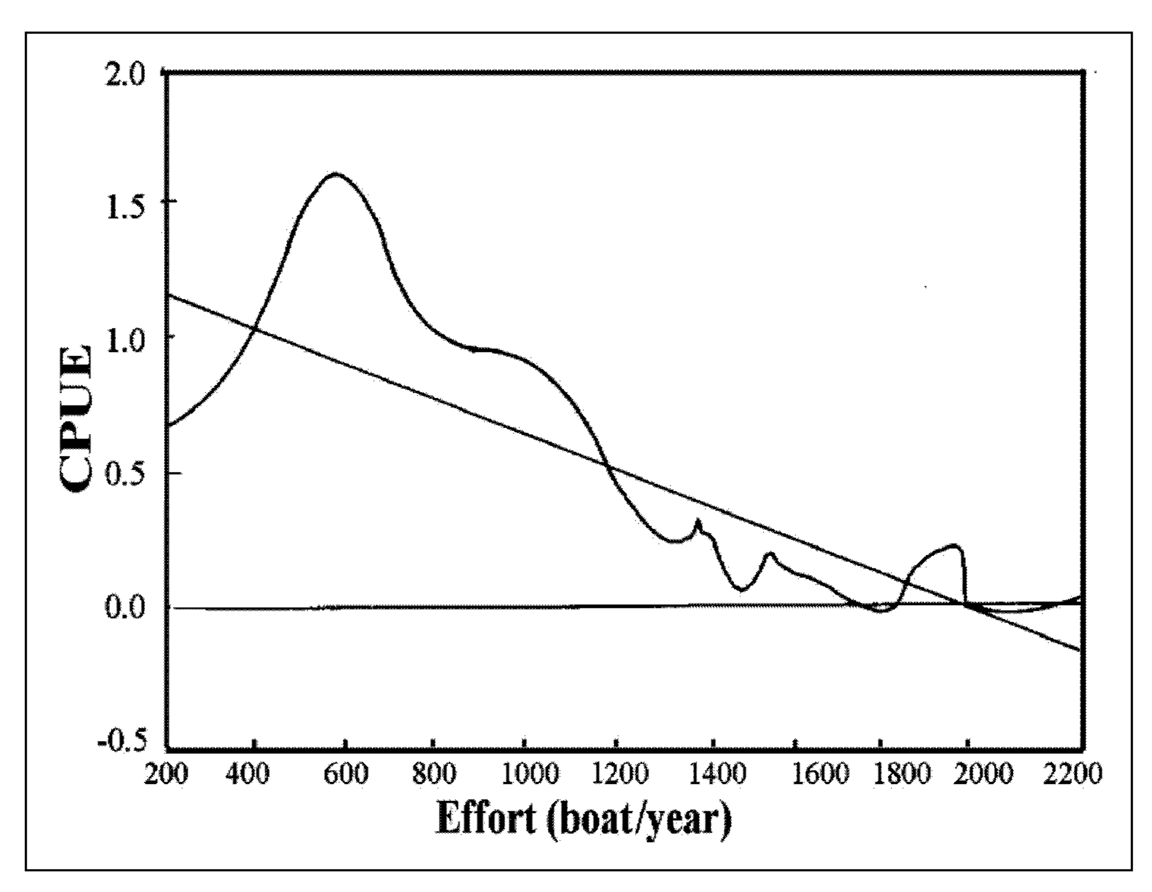


Fig. 204 CPUE-effort relationship of *Labeo* spp. (1966-1992) (Mekkawy 1996).

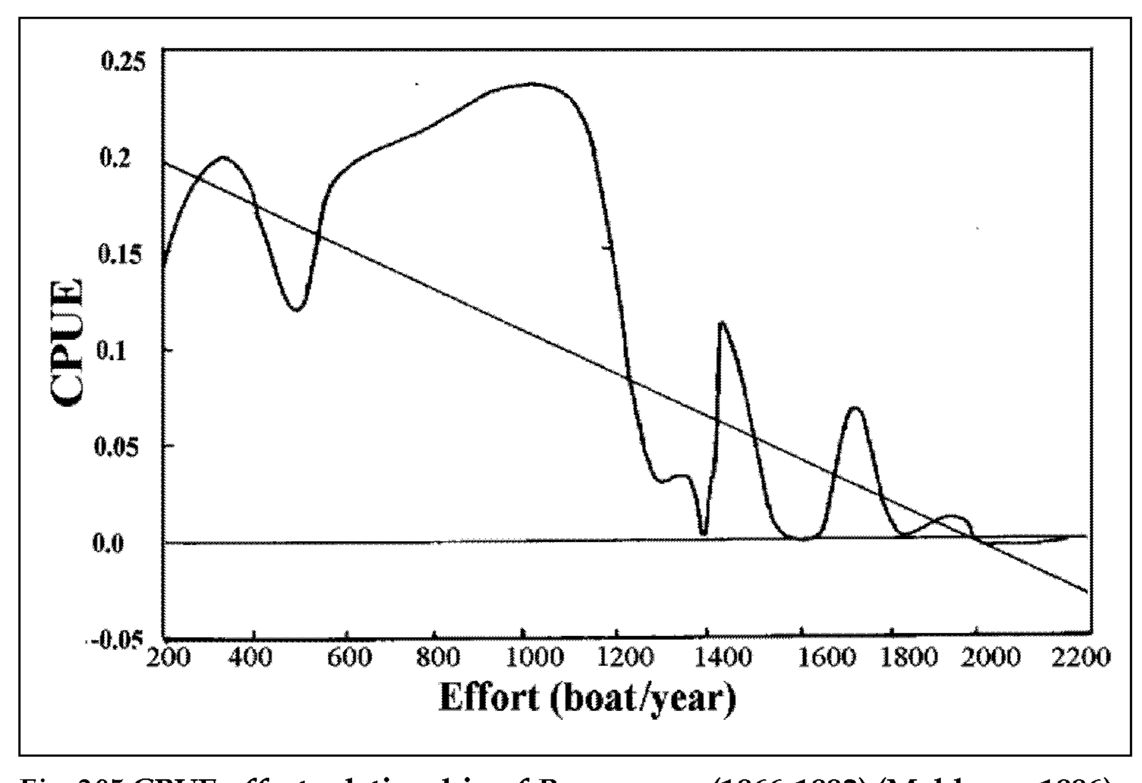


Fig. 205 CPUE-effort relationship of *Bagrus* spp. (1966-1992) (Mekkawy 1996).

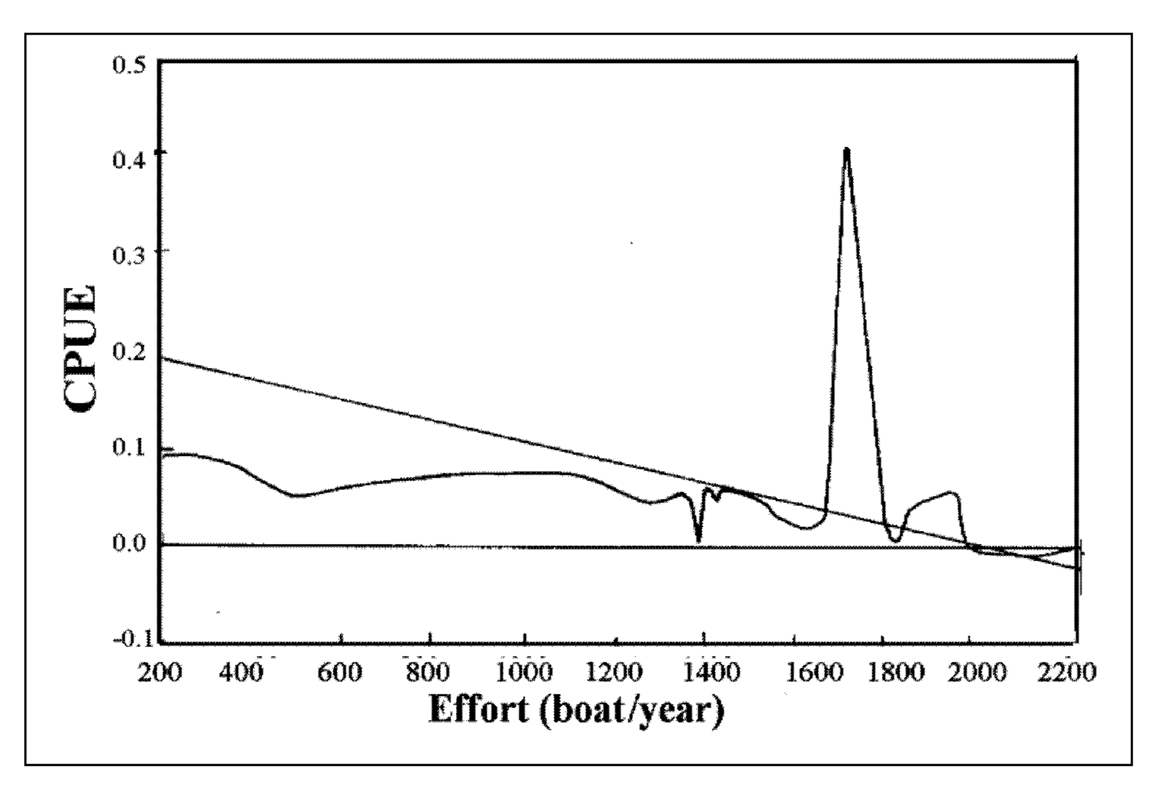


Fig. 206 **CPUE-effort relationship *of Clarias* spp. (1966-1992) (Mekkawy 1996).**

RECRUITMENT

Recruitment is the process of becoming catchable, for an individual fish it is the moment or interval during which it becomes in some degree vulnerable to capture by the fishing gear in use. Of most interest in practical fishery work is the number of recruits to the usable stock.

Mekkawy (1998) studied the effect of water level in Lake Nasser on recruitment, stock-recruitment relationships and the yield/recruitment curves (Y/R) of both *0. niloticus* and *S. galilaeus.*

Effect of water level on recruitment

Mekkawy (1998) estimated the yearly recruits (R) of *O. niloticus* and *S. galilaeus* using VPA for 1966-1992. The trends of recruitment variations with time (Y) (Fig. 207) are represented by the following equations:

For *0. niloticus* :

$$R = 1.658103E + 07 + 1056089Y \ (r = 0.41)$$

For *S. galilaeus:*

$$R = 0.443341E + 07 + 448154.3Y \ (r = 0.50)$$

Two major peaks (Fig. 207) in 1979 and 1989 were observed. The maximum numbers of recruits of *0. niloticus* were 6.089192 E + 07 and 5.66906 E

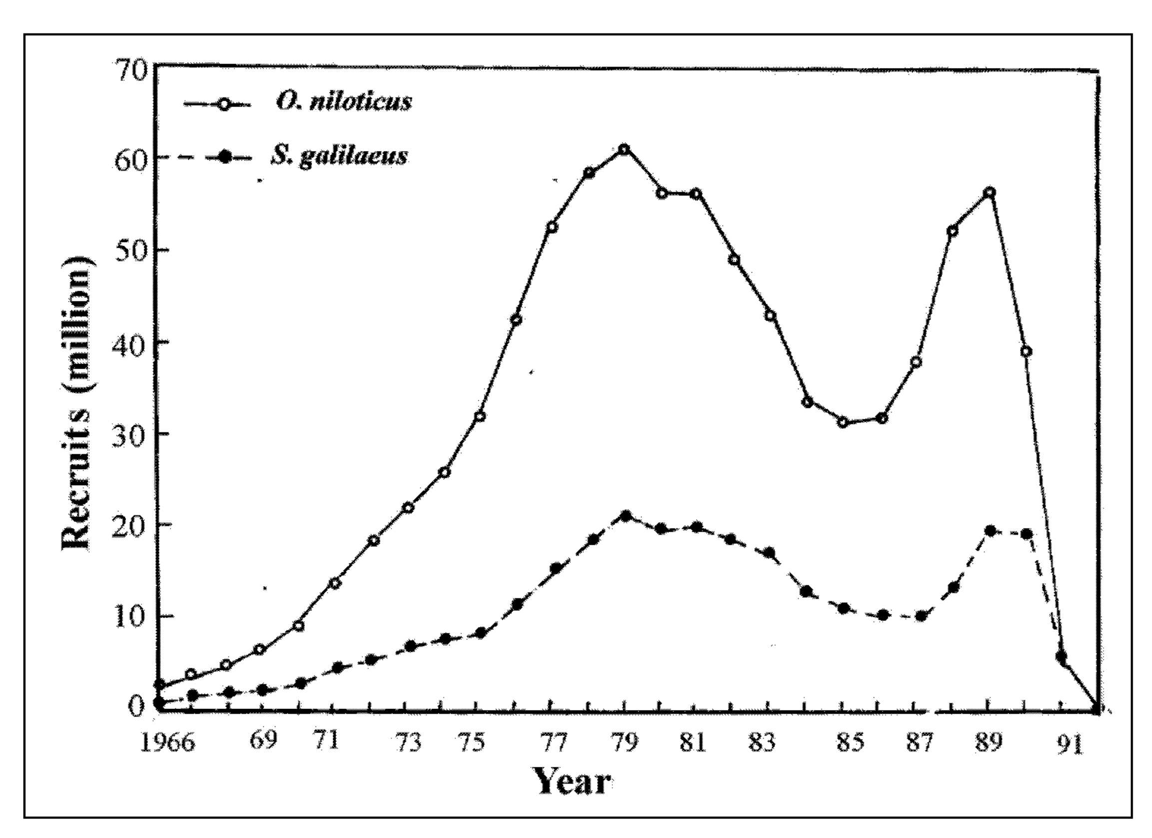


Fig. 207 **The pattern of variations of recruits of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser in 1966 - 1992 (Mekkawy 1998).**

+ 07, whereas those of *S. galilaeus* were 2.167091 E + 07 and 1.976774 E + 07 in 1979 and 1989 respectively (Mekkawy 1998).

Figs. 208 and 209 show the relationships between recruits of tilapiine species and water levels of the preceding year (WL1). The general trends were described by the following equations:

For *O. niloticus* :

$$R = -2.11296\ E + 08 + 1459529\ WL1 \qquad (r = 0.7062)$$

For *S. galilaeus:*

$$R = -1.069818\ E + 08 + 745125WL1 \qquad (r = 0.7601)$$

Mekkawy (1998) concluded that the water level of the preceding year affects the recruits of *O. niloticus* and *S. galilaeas* by 49.88 and 57.78%, whereas the other factors control them by 50.12 and 42.22% respectively. Such water-level low effects were emphasized by the correspondence of high recruitment with low values of water level (Figs. 208 and 209 - Mekkawy 1998). In some years, there was a decline in recruits in spite of high water level (Figs. 208 and 209 - Mekkawy 1998). Accordingly, the relatively high significant R-WL1 correlations of the two tilapiine species could not be reflected by their catch-WLl relationship (Mekkawy 1998).

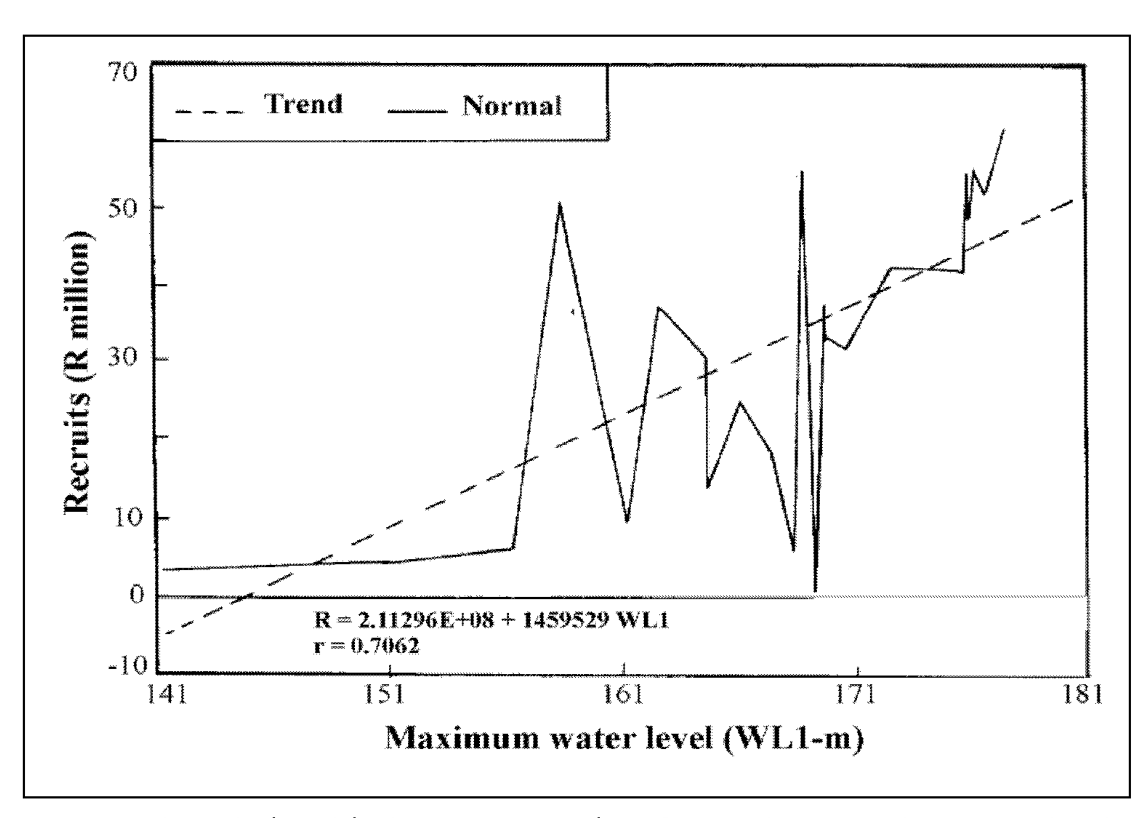


Fig. 208 **The relationship between recruits of *Oreochromis niloticus* and Lake Nasser water level of the preceding year in the 1966-1992 (Mekkway 1998).**

Stock-recruitment relationship

Mekkawy (1998) used the data of Abdel-Azim (1974) and Adam (1994) and estimated the number (mean ±SD) of eggs per gram of body weight of *O. niloticus* and *S . galilaeus* to be 2.675 ± 3.96E-01 and 5.119 ± 9.15E-01 respectively. Combination of these values with VPA results exhibits a new pattern of variations in their spawning potentials (Table 137 - Mekkawy 1998).

The latter author postulated two assumptions : either the spawning stock includes all age groups (i.e I-V or VI) or comprises only age groups III - VI and III-V for *O. niloticus* and *S. galilaeus* respectively. Accordingly, for *0. niloticus* the range of eggs / recruitment (E/R) was 1579 to 3262 and 308 to 1357 for age groups 1-VI and III-VI respectively. In case of S. *galilaeus,* it was 2690 to 6035 and 498 to 2480 for age groups I-V and III - V respectively. Such figures reflect the great loss in the eggs and pre-recruit-stage productions with respect to the two assumptions. Similar variations were recorded in the mature or spawning stock/recruitment (S/R). (Table 137 -Mekkawy, 1998).

The latter author fitted Beverton & Holt's (1957) S/R-model to stock-recruitment data of *0. niloticus* and *S. galilaeus* (Figs. 210-213) and the estimates of its parameters are given in Table 138. According to the first assumption, the S/R-relationships reflect the weak importance of density-dependent effects (and the increased density-independent effects) on the mortality, fecundity and growth of these species (Figs. 210 and 211 and the

corresponding equations). In the absence of such density-dependence, the number of recruits will be an increasing function of the abundance of the parental cohorts (the proposed steady state in the figures). Such weak density-dependent effects on populations of *O. niloticus* and *S. galilaeus* make fishing, to some extent, an additional burden of mortality imposed on these populations. Therefore, the reproductive rates of these tilapiine populations must be sufficiently high to cover this extra burden.

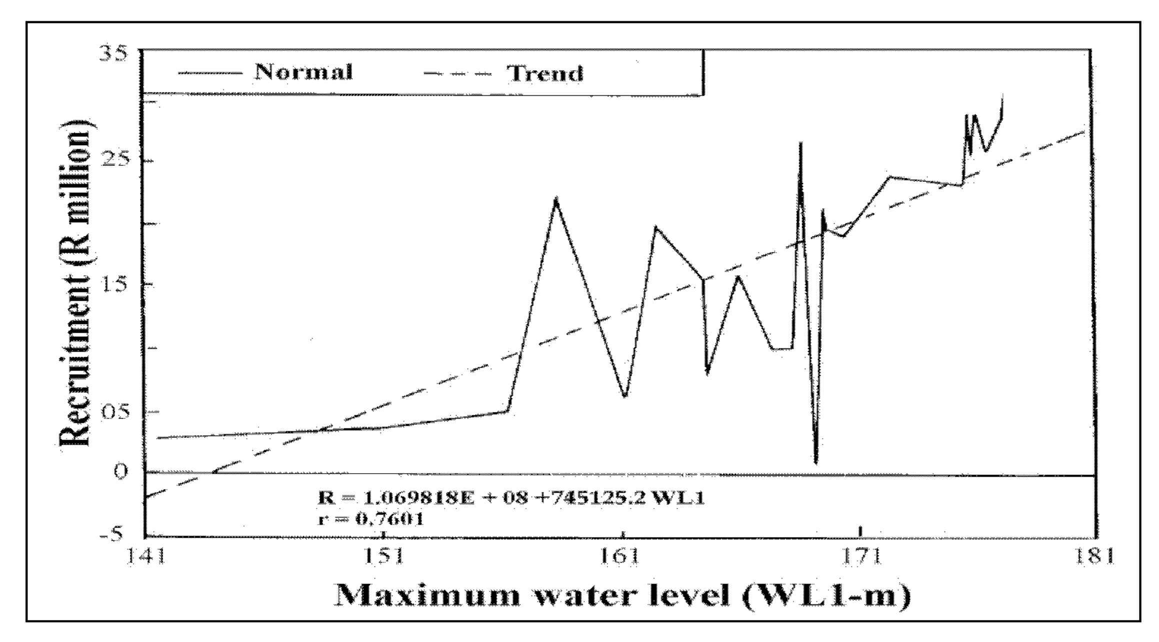


Fig. 209 **The relationship between recruits of *Sarotherodon galilaeus* and Lake Nasser water level of the preceding year in 1966-1992 (Mekkawy 1998).**

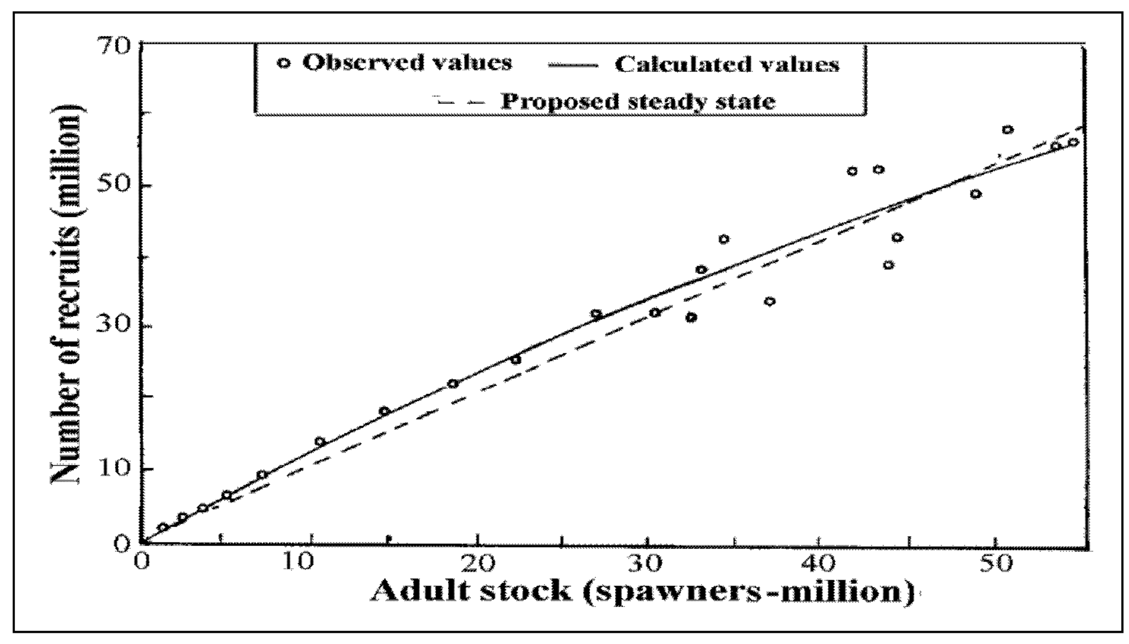


Fig. 210 **Recruitment-spawners (age groups I-VI) relationship for *Oreochromis niloticus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.* 1992) (Mekkawy 1998).**

Table 137 **The pattern of variations in egg production / recruitment and mature stock / recruitment of *0 . niloticus* and *S . galilaeus* of Lake Nasser in 1966-1992 with two assumptions for age groups shared (Mekkawy 1998).**

Year	Egg production/ recruitment				Mature stock /recruitment			
	O. niloticus		*S . galilaeus*		*O. niloticus*		*S. galilaeus*	
	Age groups shared							
	I-VI	III-V	I-V	III-V	I-VI	III-VI	I-V	III-V
1966	1579.7	307.7	3187.9	681.5	0.71	0.11	0.92	0.27
1967	1629.9	324.8	2690.1	498.3	0.72	0.12	0.80	0.20
1968	1867.6	436.3	3255.7	570.6	0.79	0.16	0.94	0.23
1969	1935.8	538.7	3902.8	1093.8	0.79	0.20	1.07	0.43
1970	1831.9	465.1	3744.9	988.8	0.77	0.17	1.04	0.39
1971	1787.4	430.4	3389.5	832.5	0.76	0.16	0.95	0.33
1972	1902.8	475.4	3770.6	902.2	0.79	0.18	1.05	0.36
1973	2077.8	595.2	4044.6	1190.8	0.83	0.22	1.10	0.47
1974	2192.7	678.7	4153.6	1164.6	0.86	0.25	1.13	0.46
1975	2127.2	662.9	4449.8	1388.9	0.84	0.24	1.19	0.55
1976	1986.5	564.9	3834.2	1105.6	0.80	0.21	1.06	0.44
1977	2036.8	566.3	3656.4	902.7	0.82	0.21	1.02	0.36
1978	2243.8	698.6	4070.8	1132.7	0.87	0.26	1.11	0.45
1979	2419.7	825.5	4250.2	1274.5	0.91	0.30	1.15	0.51
1980	2683.1	990.4	5007.1	1599.6	0.97	0.36	1.33	0.64
1981	2667.9	1039.7	4994.5	1818.3	0.96	0.38	1.31	0.72
1982	2795.7	1056.3	4959.8	1581.9	1.00	0.39	1.31	0.63
1983	2996.8	1252.6	5327.3	1969.5	1.03	0.46	1.39	0.78
1984	3201.9	1356.9	5875.9	2107.8	1.09	0.49	1.52	0.84
1985	2981.8	1298.4	6035.4	2497.9	1.02	0.47	1.54	0.99
1986	2554.1	949.0	5001.1	1708.0	0.93	0.35	1.32	0.68
1987	2274.2	776.3	4988.2	1712.9	0.87	0.28	1.31	0.68
1988	1972.3	570.1	4008.3	1237.1	0.80	0.21	1.09	0.49
1989	2177.2	614.9	3492.9	834.6	0.86	0.23	0.99	0.33
1990	3261.8	1265.9	4520.3	1267.2	1.12	0.47	1.22	0.50
1991	2371.8	1141.6	4769.2	1938.4	0.84	0.34	1.23	0.62
1992	2025.6	905.3	4088.6	1744.6	0.79	0.26	1.09	0.54

Table 138 **The parameters (α and β) of Beverton & Holt's (1957) S/R - model, fitted to stock-recruitment data of *O. niloticus* and *S. galilaeus* of Lake Nasser, the maximum number of recruits (R max) and the stock-recruitment correlation ($r_{R\&S}$) (Mekkawy 1998).**

Parameter	*O. niloticus*		*S. galilaeus*	
	Age groups shared			
	I-VI	III-VI	I-V	III-V
α	4.095846E-08	1.34011E-08	1.402931E-08	3.312858E-08
β	0.75104	0.06779	0.96316	0.14971
R max	244,149,804	74,620,740	71,279,343	30,185,417
$r_{R\&S}$	0.98	0.82	0.67	0.78

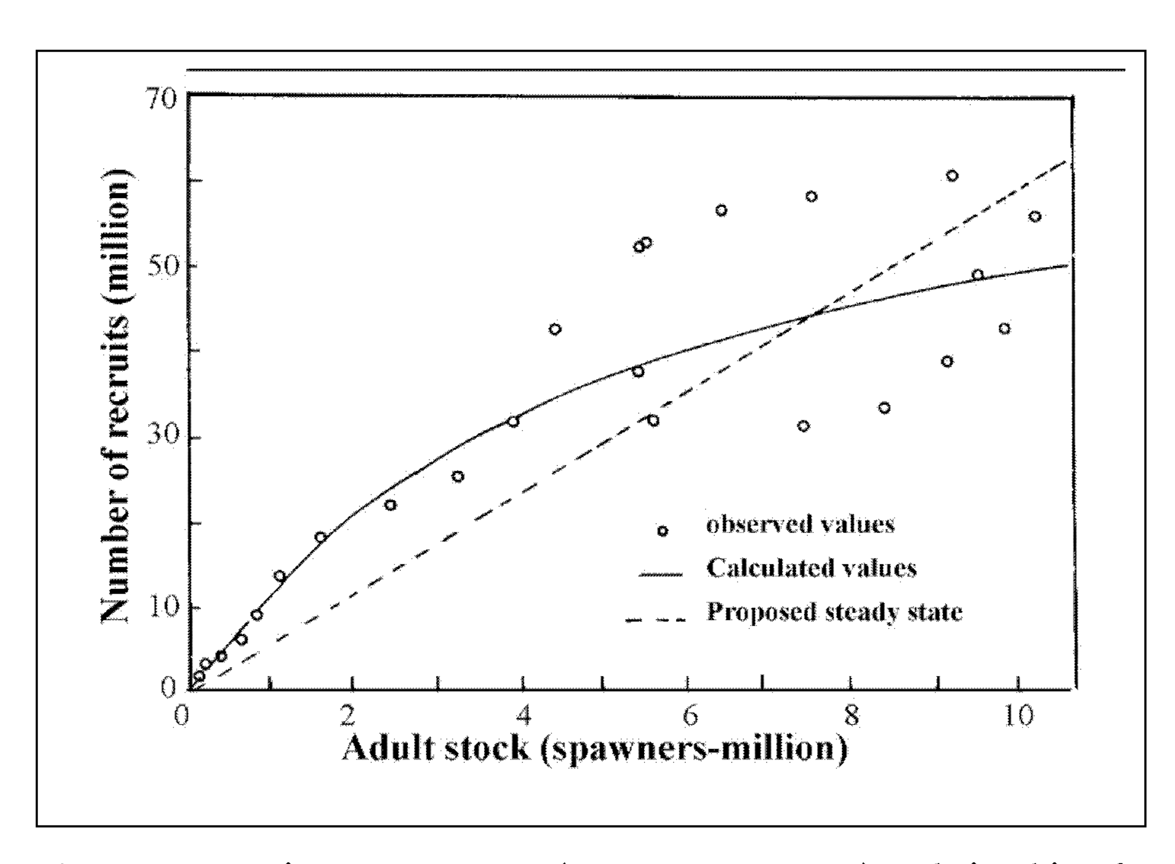


Fig. 211 Recruitment-spawners (age groups III-VI) relationship for *Oreochromis niloticus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.* 1992) (Mekkawy 1998).

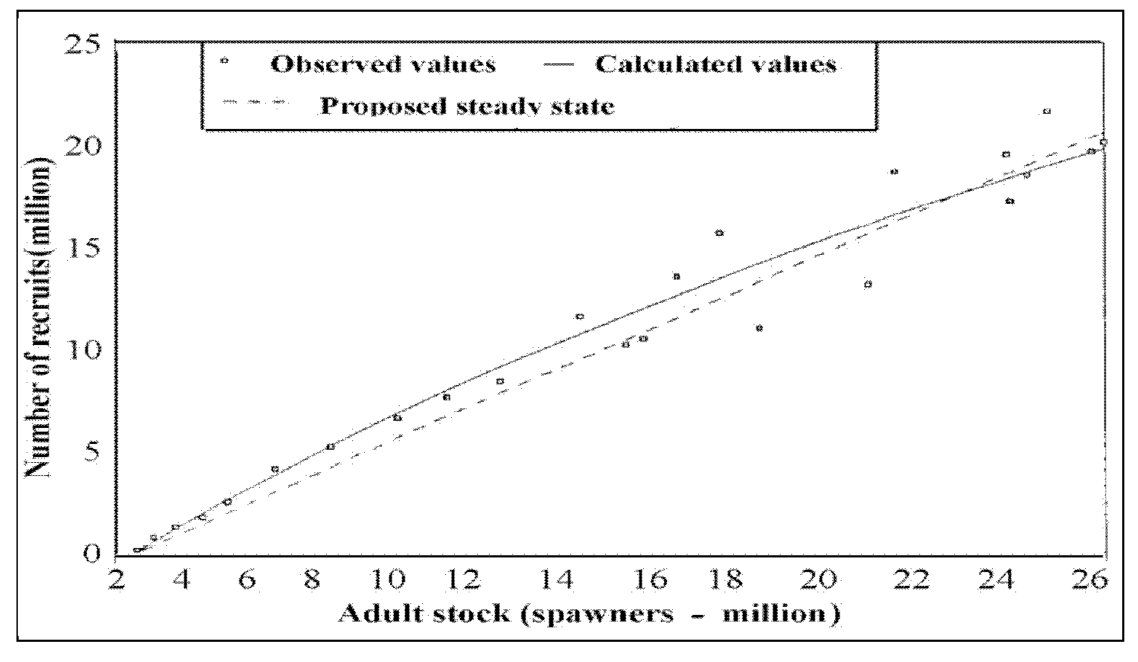


Fig. 212 Recruitment-spawners (age groups I-V) relationship for *Sarotherodon galilaeus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.*

1992) (Mekkawy 1998).

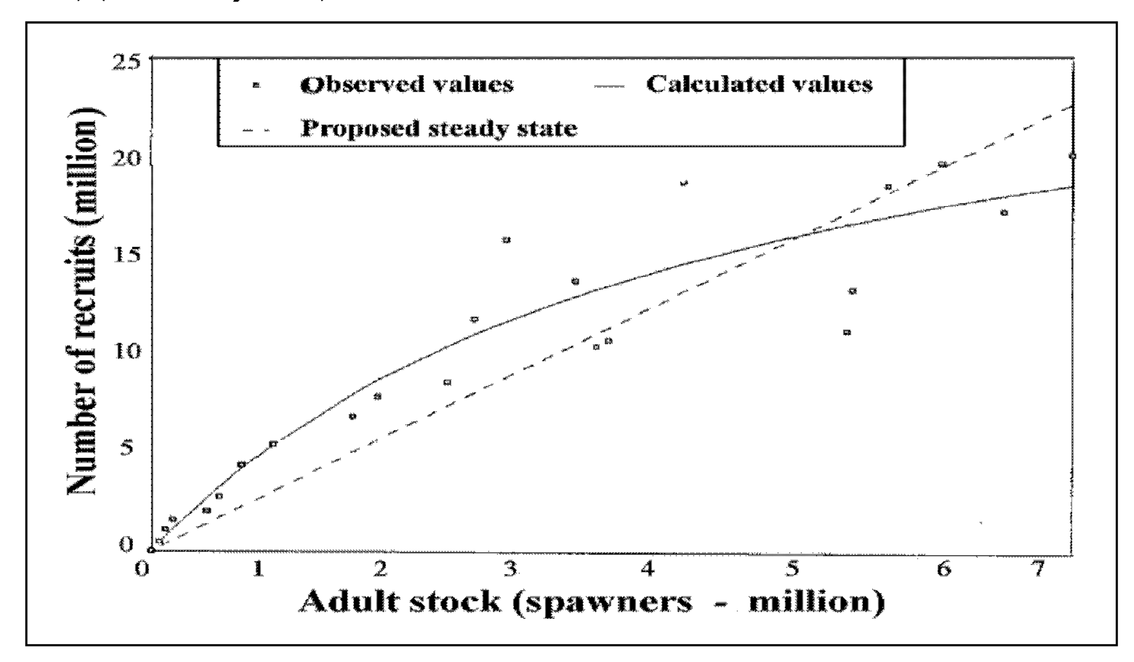


Fig. 213 **Recruitment-spawners (age groups III-V) relationship for *Sarotherodon galilaeus* of Lake Nasser fitted to Beverton & Holt's S/R-model (Sparre *et al.* 1992) (Mekkawy 1998).**

The importance of density-dependent effects increases (Figs. 211 and 213) and that of density-independent effects decreases, if the second assumption is considered (Mekkawy 1998). Consequently, the pattern of stock-recruitment relationship becomes highly different from the proposed steady state. The spawning contribution of age groups I and II cannot be excluded, because they together with age group III were represented by the highest values in the sampling process through 1965-1990 (Table 123), and some of the population characteristics of *O. niloticus* and *S. galilaeus* (e.g. early maturity) were directed towards r-selection (Mekkawy 1998). Hence, the latter author mentioned that the first assumption represents the actual status of these species in the Lake.

Although Fig. 207 indicates that recruitment of *O. niloticus* and *S. galilaeus* are variable from one year to the next, the relationship between stock and recruitment showed a pronounced trend towards increase. Such variations may be caused partially by environmental factors affecting the pre-recruit stages, and this is emphasized by low natural mortality of *O. niloticus* and *S. galilaeus,* which implies that the density-dependent factors, regulating their populations, operate before recruitment.

Mekkawy (1998) pointed out that S/R-model of Beverton & Holt (1957) supports the assumption that within a limited range of stock, recruitment appears to be independent of stock, and such a case has not been reached yet by those of *O. niloticus* and *S. galilaeus.* Using the Beverton & Holt's (1957) model, Mekkawy (1998) recorded the highest values of recruitment (24.6%) for *O. niloticus,* and 29.6%

for *S. galilaeus* of their maximum requirements during 1966-1992.

COMPUTATION OF FISH YIELD

Estimation of the fish yield (kg/ha/yr) for Lake Nasser is necessary to compare the productivity of the Lake with other African reservoirs. Hence, the total fish production from the Lake in different years and also the corresponding surface area should be calculated and /or volume based on mean water level. The relation between mean water level, average area and total volume of Lake Nasser is shown in Fig. 214. The total fish production is estimated by adding to the total landings: 10% as adjustment for self-consumption by fishermen plus 5% as adjustment for post-harvest losses (Table 139). The fish yield (kg/ha/yr) from Lake Nasser during 1968-1999 was calculated by dividing the total fish production in kilogrammes on the surface area in hectares (Table 139).

According to Baranov (1961), loeffe (1961) and Tyurin (1962), large reservoirs can be placed in one of five categories, using fish production or benthic levels as criteria (Table 140). On the basis of the aforementioned table for classification of reservoirs and according to the estimated fish yields during the whole period (1968-1999), it can be said that Lake Nasser has passed over three successive trophic states (Table 141).

1. The first trophic state is called mesohumic-mesotrophic with a fish production ranging from 15 to 30 kg/ha/yr and this happened during 1968-1971, when the minimum and maximum estimated fish yields were 18.01 and 27.52 kg/ha/year respectively.

2. The second trophic state is the mesotrophic-eutrophic (i.e. fish production 30-60 kg/ha/yr - Table 140) and this state occurred during 1972-1977, when the estimated fish yields ranged between 31.98 and 52.45 kg/ha/yr .

3. The third trophic state is eutrophic (i.e. > 60 kg/ha/yr) and occurred during 1978-1999. During this last period Lake Nasser is considered very productive so far as the fish yield increased greatly and reached 116.99 kg/ha/yr in 1985 (Table 139). Only in few years (1989, 1993, 1996 - 1999), the estimated fish yield was lower than 60 kg/ha/yr (Table 139). It is worth mentioning that in 1977, 1998 and 1999 there was a sharp drop in the estimated fish yield as it reached only 44.08, 40.11 and 28.28 kg/ha/yr respectively. This is mainly attributed to that, a high percentage of the catch is sold in the black market at high prices, and hence not recorded in the official catches. Accordingly, the true annual catches particularly those of 1997, 1998 and 1999 are not known, and so the low figures of the estimated fish yield do not represent the actual yield. Therefore, it can be said that during the period 1968-1999, Lake Nasser has gradually changed over from the mesohumic-mesotrophic state to the highly eutrophic one, if compared with the other man-made lakes of Africa as Lake Kariba (30 - 57 kg/ha/yr) or Lake Volta (43.4 kg/ha/yr).

As early as 1967, Lagler & El-Zarka, based on yield per unit surface area,

placed the eventual yield at 25,000 ton. Entz (1970) suggested that fish potential

Table 139 **Estimated fish yield based on catch statistics for Lake Nasser (1968 – 1999).**

Year	Fish landings (ton)		Total fish landings (ton)	Plus adjustment for self consumption by fishermen (10% of total landings)	Plus adjustment for post-harvest losses (5% of total landings)	Total fish production (ton)	Surface area of Lake Nasser (ha)	Estimated fish yield (kg/ha/yr)
	Fresh fish	Salted fish						
1968	1152	1510	2662	266	133	3061	170000	18.01
9	2802	1868	4670	467	234	5371	220000	24.41
1970	3370	2306	5676	568	284	6528	252500	25.85
1	4316	2503	6819	682	341	7842	285000	27.52
2	5303	3040	8343	834	417	9594	300000	31.98
3	8027	2560	10587	1059	530	12176	282500	43.10
4	8030	4225	12255	1226	613	14094	320000	44.04
5	10384	4251	14635	1464	732	15831	370000	42.79
6	10929	4862	15791	1579	790	18160	405000	44.84
7	12279	6192	18471	1847	924	21242	405000	52.45
8	17852	4873	22725	2273	1137	26135	412500	63.36
9	22649	4372	27021	2702	1351	31074	405000	76.73
1980	26344	3872	30216	3022	1511	34749	400000	86.87
1	31295	2911	34206	3421	1710	39337	385000	102.17
2	25979	2688	28667	2867	1434	32968	375000	87.91
3	28885	2397	31282	3128	1564	35974	337500	106.59
4	22069	2465	24534	2453	1227	28214	325000	86.81
5	24975	1475	26450	2645	1323	30418	260000	116.99
6	15023	1292	16315	1632	816	18763	262500	71.48
7	15287	1528	16815	1682	841	19338	240000	80.58
8	14579	1309	15888	1589	795	18272	257500	70.96
9	14031	1619	15650	1565	783	17998	330000	54.54
1990	20129	1753	21882	2188	1094	15164	327500	76.84
1	29642	1196	30838	3084	1542	35464	317500	111.70
2	24721	1498	26219	2622	1311	30152	332500	90.68
3	16723	1208	17931	1793	897	20621	370000	55.73
4	20491	1583	22074	2207	1104	25385	395000	64.27
5	19692	2366	22058	2206	1103	25367	514000	61.13
6	18160	2381	20541	2054	1027	23622	425000	55.58
7	16644	3957	20601	2060	1030	23691	537500	44.08
8	15013	4190	19203	1920	960	22083	550600	40.11
1999	9876	4106	13983	1398	699	16080	568700	28.28

of Lake Nasser may be of a magnitude comparable to Lake Volta, since fertility in Lake Nasser is considerably greater than it is for Lake Volta. Samaan (1971) considered Lake Nasser as highly eutrophic, since primary productivity ranged from 5.23 to 3.21 g C/m²/day in May. Bazigos (1972), on the basis of the trends of the catch, demonstrated mathematically that the total landings could reach

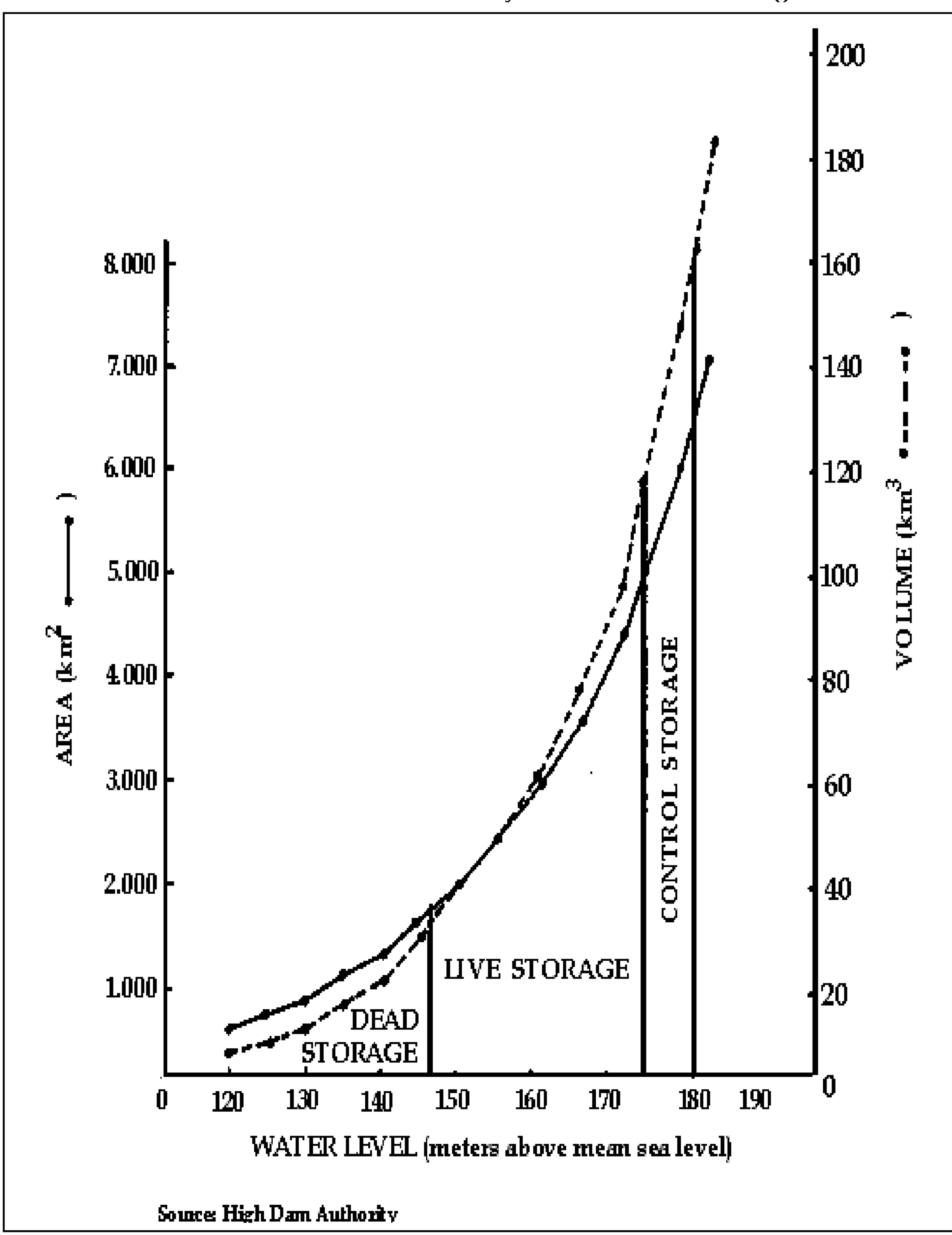


Fig. 214 **Relation between mean water level (m), average area (km²) and volume (km³) of Lake Nasser.**

about 20,000 ton by the year 1976 or 42 kg/ha/year, if the Lake area reached 4750 km^2. Using the morphoedaphic index, Ryder & Henderson (1974) estimated the potential fish yield at 160 and 180 m water levels of the High Dam Lake at 39 and 36 kg/ha/yr respectively. Corresponding fish yields were 12000 and 23000 ton/yr respectively. The actual fish landings increased from about 2662 ton in 1968 to 22,725 ton in 1978. Latif *et al.* (1979) mentioned that along the different years, the increase in fish production was from about 16kg/ha/yr for 1969-1971, 24 kg/ha/yr in 1972, about 38-40 kg/ha/yr for 1973-1976, about 44 kg/ha/yr in 1977 and ultimately 52.9 kg/ha/yr in 1978. The fish production per unit area, as it reached 55.58 kg/ha/yr in 1996, is higher than the figures recorded for other man-made lakes of Africa such as Lake Volta (43.4 kg/ha/yr) or Lake Kariba (30 - 57 kg/ha/yr). The following is a comparison between the fish yields of some African lakes.

Lake	Fish yield (kg/ha/yr)	Year
Nasser	55.58	(1996)
Albert	47-65	(1991)
Chilwa	77	(1989)
Chiala	75	(1989)
Edward	61-70	(1989)
Kariba	30-57	(1995)
Kivu	27-42	(1991)
Malawi	35-45	(1990)
Mweru	60	(1989-1990)
Tanganyika	90	(1990-1991)
Turkana	9-16	(1991)
Victoria	29-59	(1990-1991)
Volta	43.4	(1984)

Table 140 **Classification of reservoirs by fish production and by benthic production. (Baranov, 1961; Ioeffe, 1961 & Tyurin, 1962).**

Trophic state of reservoir	Fish production (kg/ha/yr)	Benthic biomass production (kg/ha/yr)
Oligotrophic	2-7	<15
Oligotrophic - mesohumic	7-15	15-30
Mesohumic - mesotrophic	15-30	30-60
Mesotrophic - eutrophic	30-60	60 - 120
Eutrophic	>60	>120

Table 141 **Classification of Lake Nasser according to the estimated fish yields (kg/ha/yr) into trophic states (1968 -1996).**

Period	Trophic states of Lake Nasser according to estimated fish yields (kg/ha/yr)		
	Mesohumic-mesotrophic (15-30 kg/ha/yr)	Mesotrophic-eutrophic (30-60 kg/ha/yr)	Eutrophic (>60 kg/ha/yr)
1968-1971	(18.01-27.52)	--	--
1972-1977	--	(31.98-52.45)	_
1978-1996	--	--	(63.36-116.99)

Prediction of potential annual yield using morphoedaphic index (MEI)

Potential fish yields from reservoirs and/or lakes were related to the morphoedaphic index (Ryder 1965) and many other investigators including Henderson & Welcomme (1974), Toews & Griffith (1979), Bernacsek & Lopes (1984), Marshall (1984) and Bishai & Khalil (1987). A review on MEI was made by Schlesinger & Regier (1982). The yield models based on MEI for African lakes and reservoirs are given in Crul (1992). Analyses of data sets used for these models revealed that data for the lakes and reservoirs selected by Henderson & Welcomme (1974) are used in most models developed later. Catch figures of some of these models were updated with data published after 1974 (Crul, 1992).

Several estimations of potential annual yield of Lake Nasser fisheries have been made. Table 142 shows mean electrical conductivity (Latif 1984b), morphoedaphic index and potential yield of certain khors and sites of open water in 1970-1977. These estimates exhibited khor-to-khor and khor-to-open water variations.

Ryder & Henderson (1975) estimated the potential yield on the basis of morphoedaphic index (Ryder 1965) as modified for tropical lakes (Regier *et al.* 1971) (10,000 ton, 39 kg/ha/y at 160 m; 19,000 ton, 36 kg/ha/y at 180 m), Rawson's (1952) mean depth model (10,000 ton, 37 kg/ha/y at 160m; 16,000 ton, 30kg/ha/y at 180 m) and Gulland's (1970) equation (11,000 ton). Vanden-Bossche & Bernacscek (1991) gave an account of some other estimations, notably by Sadek (1984) (30,000 ton, 67kg/ha/y) and Entz (1984) (35,000 ton, 78 kg/ha/y). Mekkawy (1998) applied some models (Henderson & Welcomme's 1974 and Marshall's 1984 Models) on Lake Nasser data and showed different results. After updating Marshall's (1984) Model, higher values of potential yield were obtained. This means that MEI-models must be updated before their application. However,

Table 142 **Mean conductivity (µmhos/cm) (derived from Latif 1984b), Morphoedaphic Index (MEI) and the potential yield of certain khors and open water stations in 1970-1977 at water levels 160 m (mean depth 21.6 m) and 180m (mean depth 25m) (Mekkawy 1998).**

Parameter	**I-Khors**							
	High Dam	**Kalabsha**	**Garf Hussein**	**Madiq**	**Amada**	**Tushka**	**Adindan**	**Range**
Conductivity	242.3	245.7	234.4	229.7	221.4	226.6	217.5	217.5-245.7
	According to Henderson & Welcomme's (1974) Model							
MEI at 160 m	11.22	11.37	10.85	10.63	10.24	10.49	10.07	10.07-11.37
Pot. yield	44.38	44.66	43.69	43.27	42.25	43.01	42.19	42.19-44.66
MEI at 180m	9.69	9.83	9.38	9.19	8.86	9.06	8.7	8.70-9.83
Yield (kg/ha)	41.44	41.72	40.81	40.43	39.74	40.16	39.40	39.40-41.72
	According to Marshall's (1984) Model							
MEI at 160 m	11.22	11.37	10.85	10.63	10.24	10.49	10.07	10.07-11.37
Pot. yield	68.60	69.01	67.58	66.97	65.85	66.57	65.37	65.37-69.01
MEI at 180 m	9.69	9.83	9.38	9.19	8.86	9.06	8.7	8.70-9.83
Yield (kg/ha)	64.25	64.67	63.33	62.75	61.73	62.35	61.23	61.23-64.67

Parameter	**II-Open water stations (relative to the High Dam) at distance (km)**							
	3	**50**	**100**	**140**	**200**	**250**	**290**	**Range**
Conductivity	239.5	241.8	235.0	230.6	227.0	222.9	211.8	211.8-241.8
	According to Henderson & Welcomme's (1974) Model							
MEI at 160 m	11.09	11.19	10.88	10.68	10.51	10.32	9.81	9.81-11.19
Pot. yield	44.14	44.33	43.75	43.37	43.05	42.7	41.68	41.68-44.33
MEI at 180 m	9.58	9.67	9.4	9.22	9.08	8.92	8.47	8.47-9.67
Yield (kg/ha)	41.22	41.40	40.85	40.49	40.20	39.87	38.91	38.91-41.40
	According to Marshall's (1984) Model							
MEI at 160 m	11.09	11.19	10.88	10.68	10.51	10.32	9.81	9.81-11.19
Pot. yield	68.24	68.52	67.67	67.11	66.63	66.09	64.66	64.66-68.52
MEI at 180 m	9.58	9.67	9.4	9.22	9.08	8.92	8.47	8.47-9.67
Yield (kg/ha)	63.93	64.19	63.39	62.84	62.41	61.92	60.50	60.50-64.19

Vanderpuye (1984) considered such application to underestimate the potential yield in Volta Lake by as much as two folds. The latter author pointed out that the true value of MEI could be more or less 2-folds. Mekkawy (1998) estimated the average MSY

(Maximum Sustainable Yield) by different methods and also found that they were nearly two folds the higher values estimated by the most recent MEI-based models.

Table 143 **Lake Nasser total conductivity (Vanden-Bossche & Bernacsek 1991) and the corresponding potential yield according to Henderson & Welcomme's (1974) and Marshall's (1984) Models (Mekkawy 1998).**

Mean depth (m)	Potential yield at:	
	Conductivity range 190-300 µmhos/cm	Mean conductivity 260 µmhos/cm
According to Henderson & Welcomme's (1974) Model		
25 at 180 m	36.98-45.81 kg/ha	42.84 kg/ha
	19,374.17-23,992.69 ton	22,438.18 ton
21.6 at 160m	39.61-47.05kg/ha	45.87 kg/ha
	10,238.49-12,679.21 ton	11,857.70 ton
According to Marshall's (1984) Model		
25 at 180m	57.64-70.70kg/ha	66.32 kg/ha
	30,191.93-37,030.63 ton	34,736.10 ton
21.6 at 160m	61.53-75.47kg/ha	70.79 kg/ha
	15,906.12-19,508.98 ton	18,300.14 ton

The MEI- based models reflect only one of the aspects produced by the variable ecological, environmental and fishery factors. Their validity for application is limited by their continuous updating. Therefore, administrators and fishery managers usually seek other models to obtain more precise predictions and in turn to make definitive plans for the future.

Predicting *Tilapia* spp. catch from water level and length of shoreline

The annual changes of water level, catch and the number of fishing boats are given in Fig. 215 (Yamaguchi *et al.* 1996) .The latter authors introduced a regression model for predicting tilapia catch from the water level and length of shoreline of the Lake. Tables 144 and 145 show the relation between water level and shoreline and annual changes in shoreline length during 1964-1987.

A detailed method adopted by Yamaguchi *et al.* (1996) will be given :

The following cubic equation was used for measuring the relationship between water level (H) and shoreline (L).

$$L = LO + a\,(H-HO) + b\,(H-HO)^2 + c\,(H-HO)^3 + e \quad (1)$$

where, a, b and c are constants, e is an error, HO and LO are water level and shoreline length before building the High Dam. The constants a, b and c were obtained by using the least square method. The result of calculation is shown in the following equation:

$$L = 625 + 177.8\ (H\text{-}112) - 5.054\ (H\text{-}112)^2 + 0.0587\ (H\text{-}112)^3 \quad \text{......................} (2)$$

Using this equation, the shoreline length for every year was estimated (Table 145).

Table 144 **Relation between water level and shoreline (Yamaguchi *et al.* 1996)**

Water level (m)	Shoreline (km)
112	660
150	3852.2
160	4300.4
165	4439.8
170	4625.35
175	5842
180	7859.5

Yamaguchi *et al.* (1996) found a relation between logarithm of tilapia catch and shoreline length at 1-3 years before High Dam construction. Consequently, they proposed a multiple regression formula of natural logarithm of the index of stock abundance [L_n (C_t NL_t / B_t] on the shoreline length at 0, 1, 2 and 3 years before building the Dam (equation 3).

$$L_n\ (C_t\ NL_t / B_t = b_0 + b_1NL_t + b_2NL_{t-1} + b_3NL_{t-2} + b_4NL_{t-3} \quad \text{......................} (3)$$

Where b_o, b_1, b_2, b_3 and b_4 are regression coefficients. Table 146 shows the results of regression analysis, using the full model (equation 3).

Yamaguchi *et al.* (1996) noticed that the variance inflation factor (VIF) at L_{t-2} was very high (i.e. 32), and this value suggested that multi-collinearity, using the full model (equation 3), was so strong that the latter authors selected explanatory variables by using Ridge's regression method (Chatterjee 1981-cit. Yamaguchi *et al.* 1996) (Fig. 216). Therefore, Yamaguchi *et al.* (1996) selected L_{t-3} and they made up a reduced model in the following equation:

$$L_n\ (C_t\ NL_t / B_t = b_o + b_2NL_{t-1} + b_4NL_{t-3} \quad \text{......................} (4)$$

***Table 145* Annual changes in shoreline length. (Yamaguchi *et al.* 1996).**

Year	Water level* (m)	Shoreline (km)
1964	116.4	1314
1965	123.0	2047
1966	130.0	2530
1967	138.5	2880
1968	148.5	3236
1969	153.5	3495
1970	158.5	3867
1971	163.2	4358
1972	165.5	4660
1973	161.7	4814
1974	164.0	4458
1975	169.0	5210
1976	174.5	6326
1977	174.4	6303
1978	174.8	6397
1979	175.5	6566
1980	173.6	6121
1981	172.0	5778
1982	171.5	5677
1983	169.5	5298
1984	167.3	4929
1985	160.3	4037
1986	161.2	4130
1987	158.8	3894

* Values of May of that year

The result of multiple regression analysis by using the reduced model (equation 4) is shown in Table 147. Multi-collinearity in the reduced model is small enough and adequate (VIF = 3.5).

Yamaguchi *et al.* (1996) analysed the residuals of the reduced model (Figs. 217 and 218) and they observed that the reduced model (equation 4) is reasonable and is applicable for predicting the catch and equation 4 may be

transformed into the following:

$$C_t = B_t / L_t \, N exp. (b_o + b_2 NL_{t-1} + b_4 NL_{t-3})$$

Fig. 219 shows a comparison between the estimated and the actual catches, and it is obvious that there is almost no difference between them (Yamaguchi *et al.* (1996).

Tilapia growth curve (Yamaguchi *et al.* 1996) indicated that *0. niloticus* and *S. galilaeus* recruit catch resources at 2 or 3 years old and the spawning area of tilapia is greatly affected by the shoreline length. Therefore, Yamaguchi *et al.* (1996) concluded that shoreline length at 3 years before (L_{t-3}) was selected as one of explanatory variables.

Table 146 **Result of multiple regression analysis with full model (equation [3]) (Yamaguchi *et al.* 1996).**

Variable	β*[1]	Standard error of β	VIF*[2]
L_t	-9.106E-05	1.076 E-04	8.6
L_{t-1}	3.459 E-04	1.734 E-04	26.2
L_{t-2}	- 1.483 E-04	1.732 E-04	32.2
L_{t-3}	5.803 E-04	9.674 E-05	13.0
Constants	7.217	0.182	
	N*3 = 21	R*4 = 0.987	

*1 Regression coefficient. *2 Variance inflation factor.

*3 Number of data. *4 Multiple correlation coefficient

Table 147 **Result of multiple regression analysis with reduced model (equation [4]) (Yamaguchi *et al.* 1996).**

Variable	β*[1]	Standard error of β	VIF*[2]
L_{t-1}	1.783 E-04	6.212 E-05	3.5
L_{t-2}	5.280 E-04	4.933 E-05	3.5
Constants	7.163	0.1653	
	N*3 = 21	R*4 = 0.987	

*1 Regression coefficient. *2 Variance inflation factor.

*3 Number of data. *4 Multiple correlation coefficient

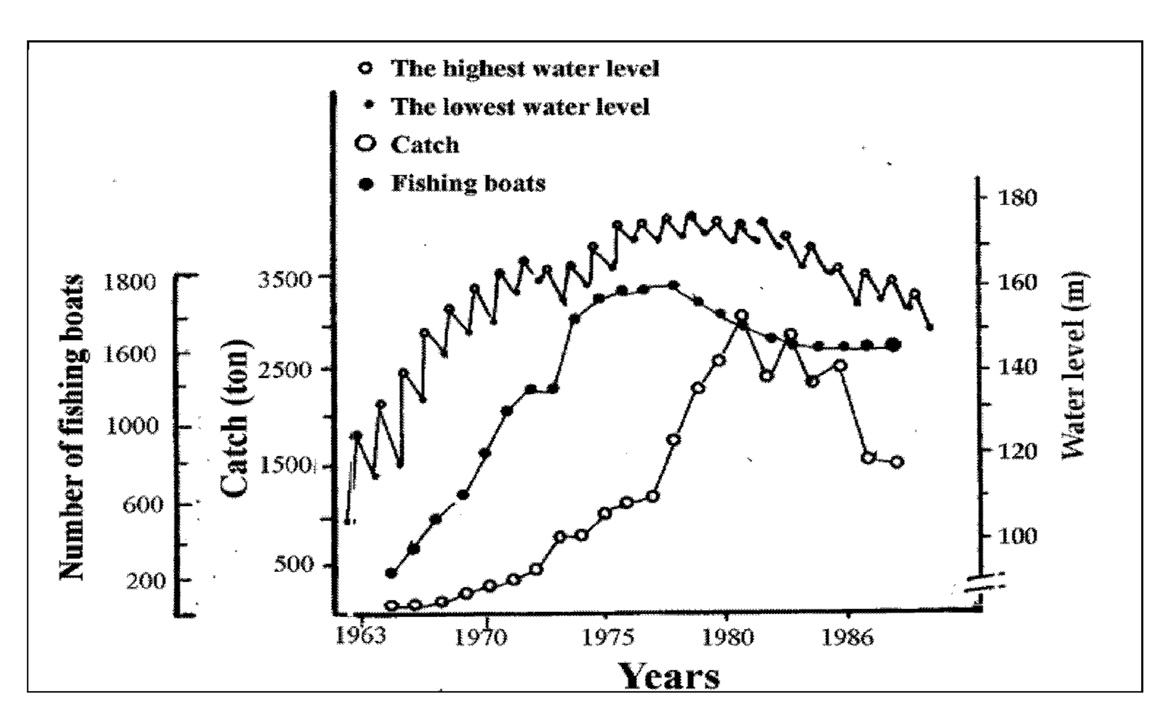


Fig. 215 **Annual changes of water level, catch and the number of boats (Yamaguchi *et al.* 1996).**

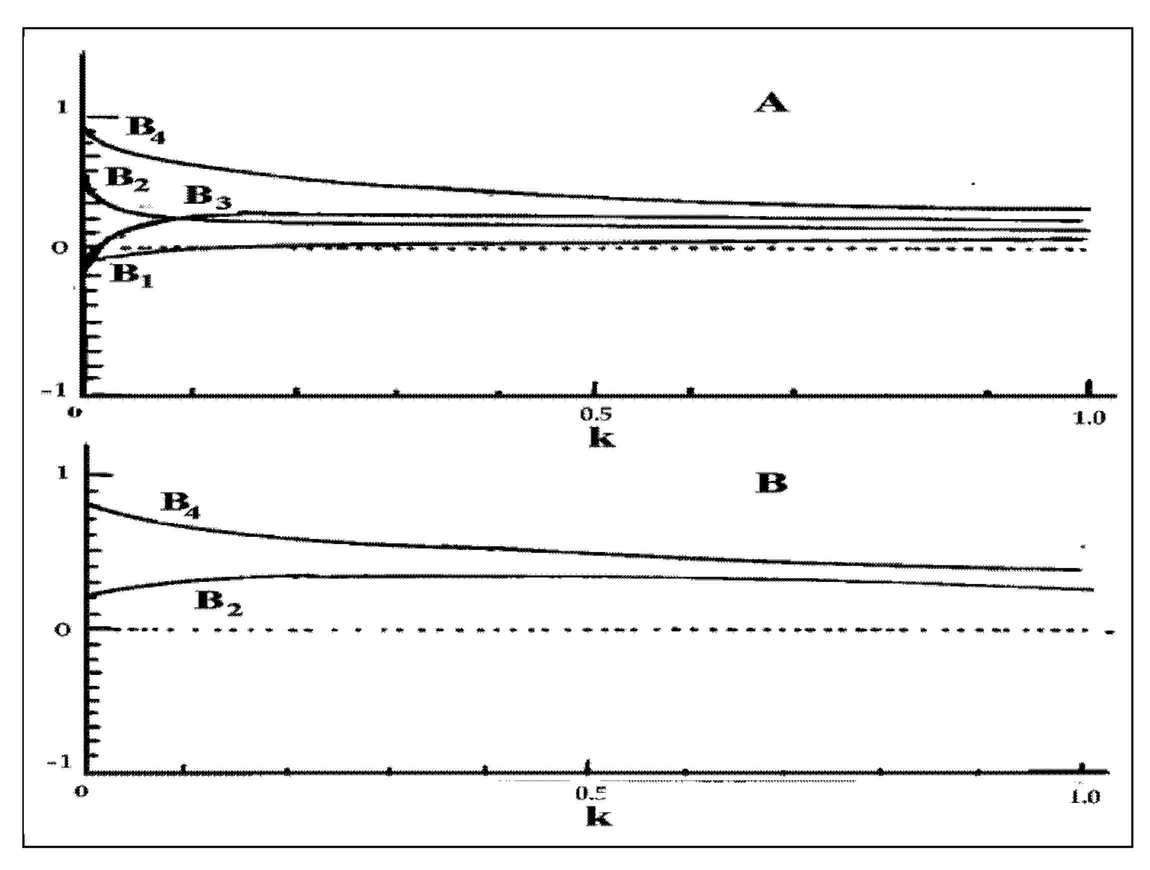


Fig. 216 Ridge's locus

A : Full model. B : Reduced model, β^{*1} : Ridge's regression coefficient

K : Ridge's parameter (Yamaguchi *et al.* 1996).

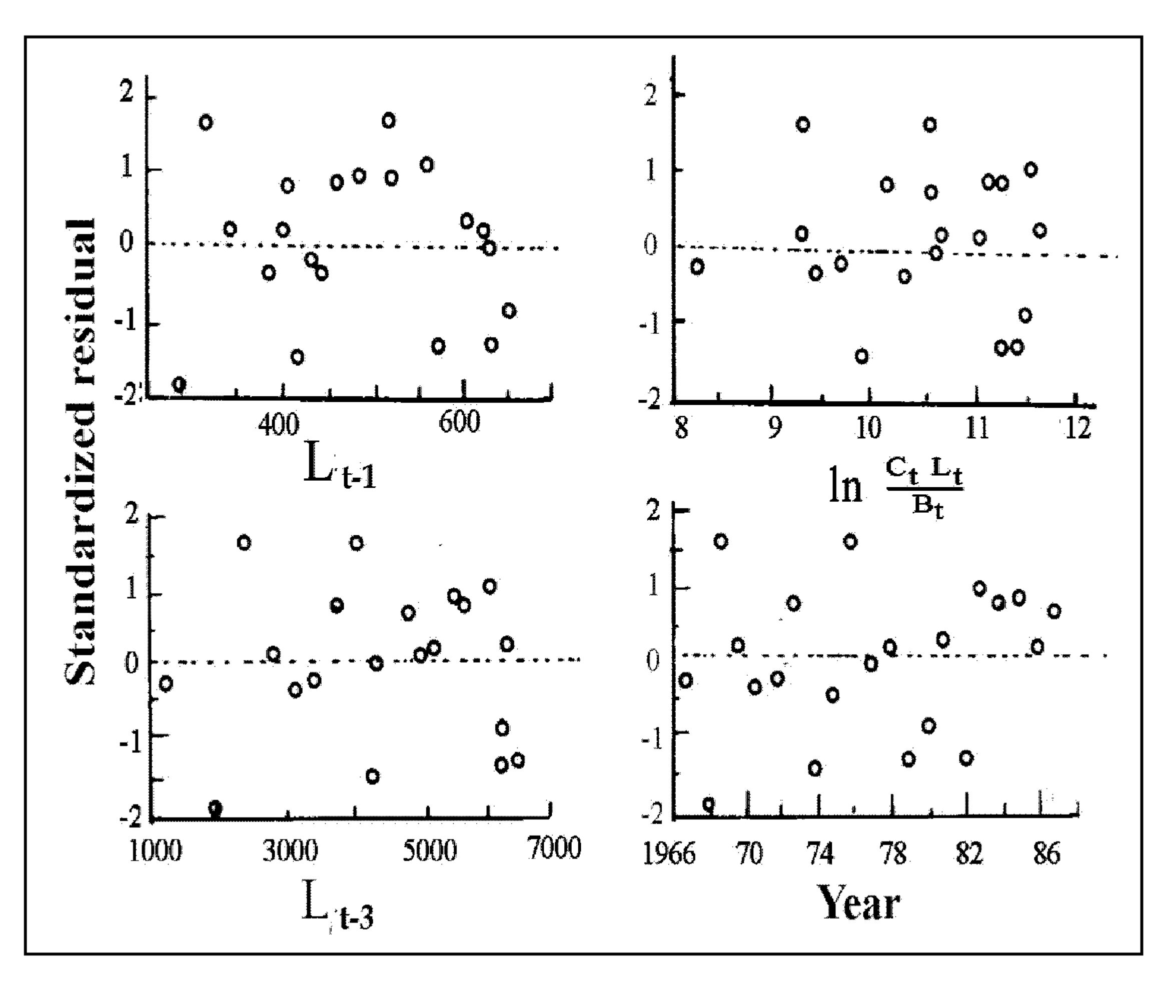


Fig 217 **Standardized residuals shown against explanation variables L_{t-1} , L_{t-3} In (C_t L_t/B_t) and year t (Yamaguchi *et al.* 1996).**

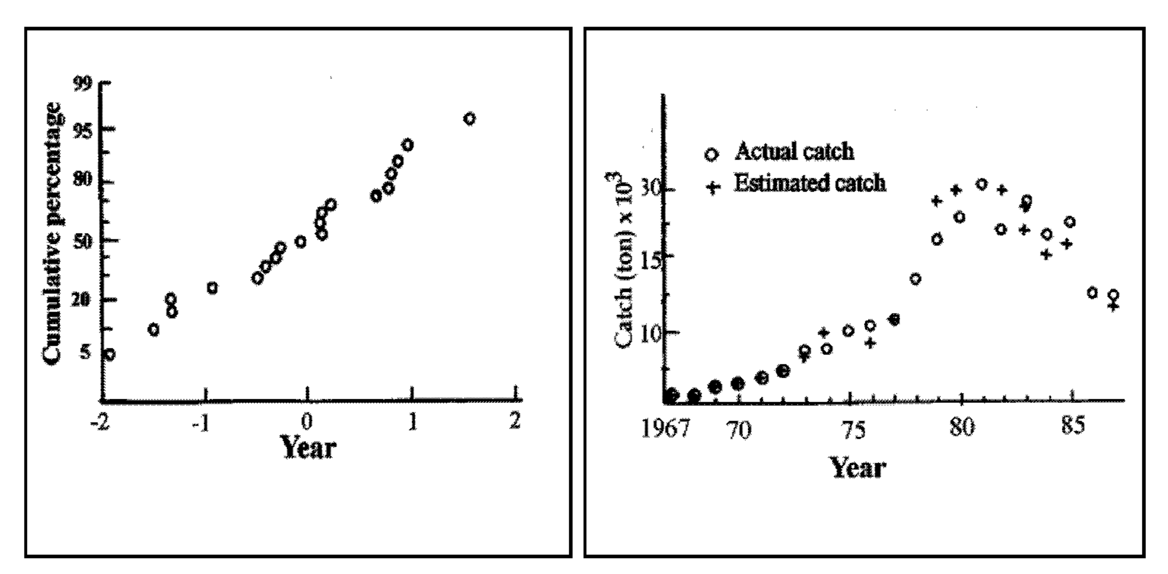


Fig 218 **Test of normality of residuals by normal probability paper,**

Fig 219 **Relation between actual and estimated catch.**

(Yamaguchi *et al.* 1996)

Tentative estimation of fish production from phytoplankton primary production.

Habib & Aruga (1987) calculated the primary net production of phytoplankton in the different fishing areas of Lake Nasser (Table 148), and in the entire Lake at 160 and 180 m above Sea level (Fig. 149).

Table 148 **Primary net production of phytoplankton in different fishing areas of Lake Nasser (for areas refer to Fig. 149) (Habib & Aruga 1987).**

Fishing area	Primary net production [kg (d.w.) /m^2/year]
1	2.88
2	5.02
3	3.83
4	5.28
5	4.51
6	2.51
Average	**4.01**

Table 149 **Primary net production of phytoplankton in the entire lake (Habib & Aruga 1987).**

Water level (m)	160	180
Surface area (km^2)	2562	5237
Surface area (m^2)	$2.56x10^9$	$5.24x10^9$
Annual net production [kg (d.w.) / year]	10.3×10^9	21.0×10^9
Annual net production [ton (d.w.) / year]	10.3×10^6	21.0×10^6

d.w. = dru weight.

For estimation of fish production, Habib & Aruga (1987) assumed that one half of primary production is consumed directly by fish (one trophic level) and the other half, indirectly by fish (two trophic levels), at a conversion efficiency of 10% (Table 150).

Table 150 **Fish production (dry weight) from Lake Nasser (Habib & Aruga 1987).**

Assumption	**Water level (m)**	
	160	**180**
Half of primary production consumed directly by fish	$5.15 \times 10^6 \times 0.1 = 5.15 \times 10^5$	$10.5 \times 10^6 \times 0.1 = 10.5 \times 10^5$
Half of primary production consumed indirectly by fish.	$5.15 \times 10^6 \times (0.1)^2 = 0.52 \times 10^5$	$10.5 \times 10^6 \times (0.1)^2 = 1.05 \times 10^5$
Total	5.67×10^5	11.55×10^5

The latter authors assumed that the fish dry weight is about 25% of the fish fresh weight and consequently the fish production could be calculated as shown in Table 151.

Table 151 **Calculated fish production (fresh weight) from Lake Nasser (Habib & Aruga 1987).**

	Water level (m)	
	160	**180**
Fish production (Fresh weight) (ton/year)	$5.67 \times 10^5/0.25 = 22.7 \times 10^5$	$11.55 \times 10^5/0.25 = 46.2 \times 10^5$

Assuming that the habitat of tilapia is only 10% of the total Lake area along the shore, tilapia production will be as follows:

	Water level (m)	
	160	**180**
Tilapia production	$22.7 \times 10^5 / 10$	$46.2 \times 10^5 / 10$
(ton/year)	22.7×10^4	46.2×10^4

Assuming that only 10% of tilapia are caught, the tilapia catch will be as follows:

	Water level (m)	
	160	180
Tilapia catch	22.7×10^4 / 10 22.7×10^3 ton / year	46.2×10^4 / 10 46.2×10^3 ton / year

ESTIMATION OF MAXIMUM SUSTAINABLE YIELD (MSY)

Estimation of maximum sustainable yield (MSY) using some population characteristics

Mekkawy (1998) calculated some population characteristics of *O. niloticus, S. galilaeus* and *Lates niloticus*. The latter author estimated the maximum sustainable yield of the aforementioned fish species of Lake Nasser during 1966-1992 (Tables 152-154). The MSY was roughly estimated according to Cadima's estimator (Troadec, 1977). However, these yearly variable MSY's values were overestimated since they were influenced only by yearly catch and total mortality and not by long-term data (Mekkawy 1998).

Estimation of maximum sustainable yield (MSY) using yield / recruitment and biomass/recruitment relationships

Sparre *et al.* (1992) mentioned that yield per recruit (Y/R) model of Beverton & Holt (1957) is in principle a "steady state model". This model can be written according to Gulland (1970) in the following form:

$$Y/R = F * \exp[-M*(Tc - Tr)] * W_\infty * [1/Z - 3S/(Z + k) + 3S^2 (Z + 2k) - S^3/(Z + 3k)]$$

Where S = exp [-K* (Tc - To);	k = von Bertalanffy growth parameter,
Tc = age at first capture;	Tr = age at recruitment;
W_∞ = asymptotic body weight;	F = fishing mortality;
M = natural mortality;	Z = total mortality; Z = F + M.

Mekkawy (1998) used the aforementioned model in calculating Y/R with varying inputs of different values of Tc and F. The latter author used also Beverton & Holt's biomass per recruit (B/R) and relative Y/R models (Sparre *et al.* 1992) in estimating MSY/R and the relative MSY/R for different values of Tc.

The yield / recruitment curves (Y/R) of *0. niloticus* differed in shape and characteristics from those of *S. galilaeus* (Fig. 220 and 221). Thus, Y/R - curves of the latter species had pronounced maximum values and correspondingly lower values of fishing mortality, F_{MSY} in comparison with those of the first species (Mekkawy 1998). The lower value of the natural mortality rate (M) of *S. galilaeus* produced the lower F_{MSY} and higher MSY/R. The latter author mentioned that this situation pays to let *S. galilaeus* to grow to a large size and this means that for a biological optimum exploitation, fishing mortality should be low.

***Table** 152* **Certain population characteristics and the maximum sustainable yield (MSY) of *Oreochromis niloticus* of Lake Nasser in 1966-1992 (Mekkawy 1998).**

Year	Population characteristics *					MSY** (ton)
	F	Z	μ	E	V	
1966	0.144	0.765	0.189	0.101	0.434	2554.5
1967	0.253	0.873	0.289	0.169	0.414	2823.2
1968	0.361	0.982	0.368	0.230	0.395	3362.6
1969	0.432	1.053	0.411	0.267	0.384	8353.8
1970	0.589	1.210	0.487	0.342	0.360	8490.5
1971	0.750	1.371	0.547	0.408	0.338	10005.4
1972	0.819	1.440	0.569	0.434	0.329	12636.6
1973	1.047	1.667	0.628	0.509	0.302	19832.2
1974	1.078	1.698	0.635	0.518	0.299	19797.3
1975	1.255	1.875	0.669	0.566	0.280	25040.1
1976	1.040	1.660	0.626	0.507	0.303	29134.2
1977	1.039	1.659	0.626	0.507	0.303	31028.4
1978	0.948	1.568	0.604	0.478	0.313	48588.9
1979	0.990	1.611	0.615	0.492	0.308	63040.6
1980	1.027	1.647	0.623	0.503	0.304	70793.9
1981	1.431	2.051	0.697	0.608	0.264	75906.5
1982	1.127	1.747	0.645	0.533	0.293	63771.5
1983	1.346	1.966	0.684	0.589	0.271	71513.9
1984	1.135	1.755	0.646	0.535	0.292	61332.7
1985	1.197	1.817	0.659	0.552	0.286	61298.3
1986	1.010	1.631	0.619	0.498	0.306	41804.2
1987	1.010	1.631	0.619	0.498	0.306	40734.6
1988	1.014	1.635	0.620	0.499	0.306	38848.6
1989	1.626	2.247	0.724	0.647	0.247	31167.9
1990	1.626	2.247	0.724	0.647	0.247	46874.1
1991	1.437	2.058	0.698	0.609	0.263	72962.1
1992	1.333	1.953	0.682	0.586	0.273	61352.7

**** roughly estimated according to Cadima's estimator (Troadec, 1977).**
F= fishing mortality, Z = total mortality, μ & E = ratio and rate of exploitation, V = expectation of natural death.

Table 153 **Certain population characteristics and the maximum sustainable yield (MSY) of *Sarotherdon galilaeus* of Lake Nasser in 1966-1992 (Mekkawy 1998).**

Year	Population characteristics *					MSY** (ton)
	F	Z	μ	E	V	
1966	0.277	0.345	0.803	0.234	0.057	365.1
1967	0.484	0.552	0.877	0.372	0.052	566.4
1968	0.692	0.760	0.911	0.485	0.048	825.8
1969	0.829	0.897	0.924	0.547	0.045	2257.1
1970	1.129	1.197	0.943	0.658	0.040	2665.6
1971	1.438	1.505	0.955	0.743	0.035	3486.9
1972	1.570	1.638	0.959	0.772	0.033	4561.9
1973	2.006	2.074	0.967	0.846	0.029	7828.9
1974	2.066	2.133	0.968	0.854	0.028	7891.5
1975	2.405	2.472	0.973	0.891	0.025	10476.3
1976	1.992	2.060	0.967	0.844	0.029	11472.7
1977	1.991	2.059	0.967	0.844	0.029	12215.7
1978	1.817	1.884	0.964	0.818	0.031	18524.8
1979	1.898	1.966	0.965	0.830	0.030	24412.8
1980	1.967	2.035	0.967	0.840	0.029	27758.0
1981	2.742	2.810	0.976	0.917	0.023	32994.9
1982	2.160	2.228	0.970	0.865	0.027	25795.8
1983	2.579	2.647	0.974	0.905	0.024	30547.9
1984	2.175	2.243	0.970	0.867	0.027	24865.8
1985	2.294	2.362	0.971	0.880	0.026	25276.4
1986	1.936	2.003	0.966	0.836	0.029	16299.3
1987	1.936	2.003	0.966	0.836	0.029	15882.3
1988	1.944	2.012	0.966	0.837	0.029	15169.4
1989	3.117	3.185	0.979	0.938	0.020	14018.8
1990	3.117	3.185	0.979	0.938	0.020	21083.1
1991	2.755	2.823	0.976	0.918	0.023	31754.9
1992	2.554	2.622	0.974	0.903	0.024	26133.6

Refer to table 152 for abbreviations ** roughly estimated according to Cadima's estimator (Troadec, 1977).

Table 154 **Certain population characteristics and the maximum sustainable yield (MSY) of *Lates niloticus* of Lake Nasser in 1966-1992 (Mekkawy 1998).**

Year	Population characteristics *					MSY**
	F	Z	μ	E	V	(ton)
1966	0.062	0.284	0.218	0.054	0.193	172.2
1967	0.108	0.330	0.328	0.092	0.189	617.9
1968	0.154	0.376	0.410	0.129	0.185	1297.3
1969	0.185	0.407	0.455	0.152	0.182	4766.1
1970	0.252	0.474	0.532	0.201	0.177	6359.3
1971	0.312	0.543	0.591	0.248	0.171	6557.6
1972	0.351	0.573	0.612	0.267	0.169	5522.7
1973	0.448	0.670	0.669	0.327	0.162	4418.5
1974	0.461	0.683	0.675	0.334	0.161	5442.7
1975	0.537	0.759	0.708	0.376	0.155	5564.5
1976	0.445	0.667	0.667	0.325	0.162	4675.9
1977	0.445	0.666	0.667	0.325	0.162	6340.9
1978	0.406	0.628	0.646	0.301	0.165	4849.7
1979	0.424	0.646	0.656	0.312	0.163	4238.9
1980	0.439	0.661	0.664	0.321	0.162	4887.5
1981	0.612	0.834	0.734	0.415	0.150	4076.7
1982	0.482	0.704	0.684	0.346	0.159	3000.4
1983	0.576	0.798	0.722	0.397	0.153	2659.7
1984	0.486	0.708	0.686	0.348	0.159	1464.1
1985	0.512	0.734	0.698	0.363	0.157	1386.6
1986	0.432	0.654	0.661	0.317	0.163	2837.5
1987	0.432	0.654	0.661	0.317	0.163	3484.4
1988	0.434	0.656	0.662	0.318	0.163	6199.4
1989	0.696	0.918	0.758	0.455	0.145	7012.4
1990	0.696	0.918	0.758	0.455	0.145	4707.9
1991	0.615	0.837	0.735	0.417	0.150	2561.5
1992	0.570	0.792	0.720	0.394	0.153	6083.9

Refer to table 152 for abbreviations ** roughly estimated according to Cadima's estimator (Troadec 1977).

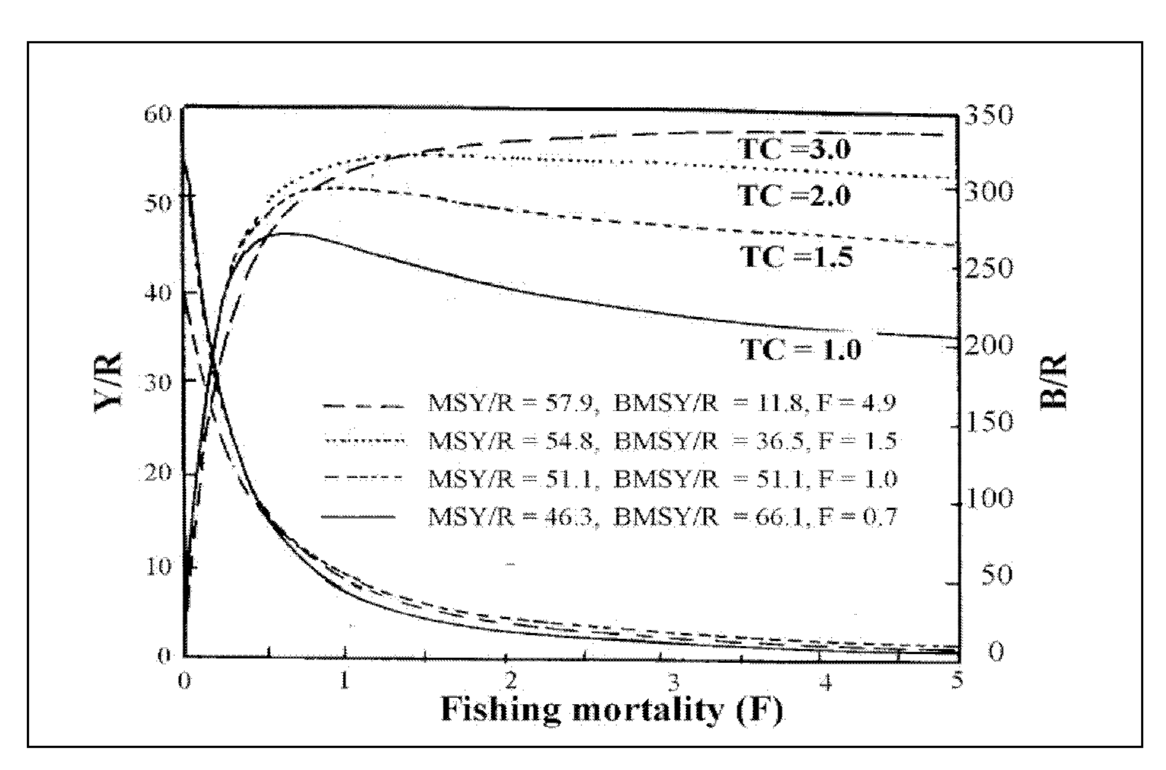


Fig. 220 **Yield/recruit (Y/R) and biomass/recruit (B/R) curves with different ages at first capture (TC) of *Oreochromis niloticus* of Lake Nasser (Mekkawy 1998).**

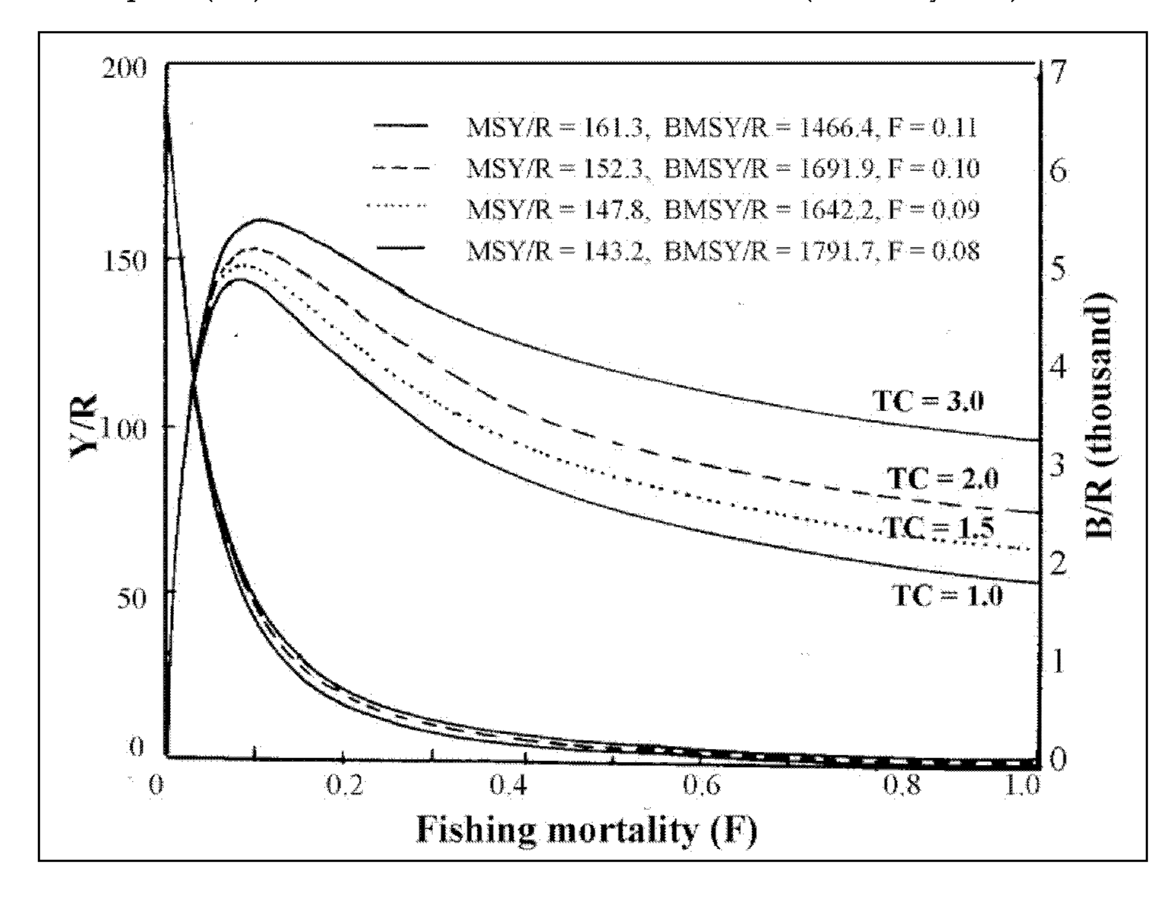


Fig. 221 **Yield/recruit (Y/R) and biomass/recruit (B/R) curves with different ages at first capture (TC) of *Sarotherodon galilaeus* of Lake Nasser (Mekkawy 1998).**

The MSY/R of both *0. niloticus* and *S. galilaeus* increases with the increase of age at first capture, Tc (Figs. 220 and 221). The recruits required to obtain MSY of F_{MSY} (30,000 ton) are 647,948,164 and 518,134,715 for Tc = 1 and 3 respectively. When comparing these values with those of 1979-cohort, Mekkawy (1998) concluded that the environmental and biological conditions of the Lake should be controlled to multiply the current recruits of *O. niloticus*, at least by a factor of 9-11 for MSY (30,000 ton) at Tc = 1 – 3). The latter author postulated that those of *S. galilaeus* should be multiplied by at least a factor of 5 - 6 for MSY (17,000 ton) at Tc = 1 - 3.

Figs. 220 and 221 show that the annual average biomass of the survivors was expressed as a function of fishing mortalities of tilapiine species considered. The biomass of these species declines with the increase of fishing effort. In other words, their biomass per recruit (B/R) curves were proportional to CPUE, which means that one should expect a decrease in CPUE and their biomass when effort increases (Mekkawy 1998).

Therefore, a decrease in CPUE is not per se an indication that a stock is overfished. In fact, overfishing occurs when the effort becomes so high that the growth curve cannot balance the death process.

Table 155 shows that the percentages of biomass corresponding to the biologically optimum F-level, (B_{MSY}) relative to the virgin stock biomass (Bv), the biomass of unexploited stock, at different ages of first capture were represented by 5.02-19.92% for *O. niloticus* and 21.95-26.37% for *S. galilaeus.* The reduction in the spawning stock biomass of these species will influence the productivity of their stocks. Below such a level of reduction (B_{MSY}) the stock of *O. niloticus* and *S. galilaeus* will be recruitment - overfished (Mekkawy 1998).

Two types of Y/R-curves are observed (Figs. 220 and 221). Fig. 220 shows a plateau type of curve, which is virtually asymptotic for most purposes. At Tc > 2, *0. niloticus* Y/R increases to a plateau with increasing fishing mortality. Beyond its first part, a large increase in fishing mortality produces only a very small increase in yield. In the remaining curves, especially those of *S. galilaeus,* a definite peak of yield is reached at a relatively low fishing mortality. At first sight, the management policies suggested by the two types of curves are very different (Mekkawy 1998). The first seems to indicate maximum yields from heavy fishing, whereas the second advocates low to moderate fishing mortality. The latter author mentioned that this conclusion is misleading and in fact, the actual shape of these Beverton & Holt yield curves varies according to the relationship between growth rate and age at first capture, Tc.

Table 155 **Optimum fishing mortality (F_{MSY}), maximum sustainable yield per recruit (MSY/R), corresponding biomass per recruit (B_{MSY}/R) virgin stock per recruit (Bv/R) and the percentage of B_{MSY} relative to Bv at different ages of first capture, Tc, and according to the current growth characteristics of *O. niloticus* and *S. galilaeus* of Lake Nasser (Mekkawy 1998).**

F_{MSY}	MSY/R	B_{MSY}/R	B_V/R	B_{MSY}/B_V (%)	Tc
			O. niloticus		
0.7	46.3	66.1	332.0	19.92	1.0
1.0	51.1	51.1	313.8	16.28	1.5
1.5	54.8	36.5	290.4	12.58	2.0
4.9	57.9	11.8	234.9	5.02	3.0
			S. galilaeus		
0.08	143.3	1791.7	6793.9	26.37	1.0
0.09	147.8	1642.2	6773.6	24.24	1.5
0.10	152.3	1691.9	6748.4	25.07	2.0
0.11	161.3	1466.4	6681.9	21.95	3.0

Mekkawy (1998) mentioned that S. *galilaeus,* which is of a slow growing nature, and is caught early in life, has a lot of potential weight to put on, and this brings about a maximum yield at low fishing rates. Such low rates allow fish to escape the gear and therefore realize some of their growth potential. On the other hand, *0. niloticus* tends to be fast-growing and producing Y/R-curve of the plateau type even at lower rates of Tc.

Mekkawy (1998) considered the relative Y/R-concept of Beverton & Holt (1966), and his results concerning MSY/R, E_{MSY}, F_{MSY}, Tc, Lc and the corresponding mesh size for these tilapiine species are presented in Table 156. For *0. niloticus,* if Tc increases above 3, it will be difficult to determine E_{MSY}, except at very heavy fishing.

Estimation of maximum sustainable yield (MSY) using Schaefer's Model

Mekkawy (1998) fitted khor's catch-effort data of 1988-1994 to Schaefer's Model and estimated the MSY per month per fishing area, and presented also the effort and CPUE ranges in Tables 157 and 158. Using khor's MSY, Mekkawy (1998) estimated the total MSY of the Lake as 59,742.24 ton, 52.14% (= 31,150.2 ton) of that value was contributed by the northern part of the Lake and 47.86%

(= 28,592.4 ton) by the southern part. The average MSY per fishing area was 798.72 and 722.75 ton per year for the northern and southern parts respectively. Three khor fishing areas were out of calculations due to the positive CPUE-effort correlations (Table 157 and 158).

Table 156 **Relative maximum sustainable yield [(MSY/R)] and the corresponding optimum exploitation rate (E_{MSY}), and optimum fishing mortality rate (F_{MSY}) at different ages of first capture, Tc, and the corresponding total length, Lc and mesh size and according to the current characteristics of *O. niloticus* and *S. galilaeus* of Lake Nasser (Mekkawy 1998).**

(MSY/R)	E_{MSY}	F_{MSY}	Tc	Lc	Mesh size
O. niloticus **** (selection factor = 1.93)**					
0.005619	0.492	0.60	1.0	11.88	6.15
0.008450	0.617	1.00	1.5	14.64	7.58
0.012378	0.733	1.70	2.0	17.28	8.95
0.017675	0.869	4.90	2.5	19.81	10.26
0.024649	0.981	31.6	3.0	22.23	11.52
S. galilaeus **(selection factor = 2.03)**					
0.10535	0.588	0.10	1.0	12.26	6.05
0.11093	0.632	0.12	1.5	13.42	6.62
0.11707	0.650	0.13	2.0	14.52	7.16
0.17375	0.680	0.15	2.5	15.58	7.69
0.13113	0.695	0.16	3.0	16.59	8.18
0.13922	0.731	0.19	3.5	17.55	8.66
0.14810	0.759	0.22	4.0	18.48	9.11
0.15786	0.788	0.26	4.5	19.36	9.55
0.16860	0.816	0.31	5.0	20.20	9.96

**** For Tc > 3, $E_{MSY} \approx 1.0$ and (MSY/R)-increase requires very high F_{MSY}.**

Mekkawy (1998) mentioned that the total-catch-effort data of the whole period (1966-1992) were fitted to the power function equation (Fig. 222). These data were best described by the following equation:

$$\text{Catch (C)} = 0.148928\ f^{1.5975378}$$

which may also take the form :

$$\text{CPUE} = 0.148928\ f^{1.5975378}$$

The power function model has no maximum and therefore, maximum sustainable yield (MSY) and the corresponding fishing effort (f_{MSY}) cannot be determined. This model could be considered here as a descriptive one (Mekkawy 1998).

The total-catch-effort data of the fluctuated period (1973-1992) were fitted to the hyperbolic model (Fig. 223) and was described by the following equation:

Table 157 **Estimation of maximum sustainable yield (MSY) per month and the related optimum effort (f_{MSY}) of the fishing grounds of the northern part of Lake Nasser based on the data of Mohamed, M. (1993a, b, 1995a, b) for 1988-1994. Monthly effort and catch per unit effort (CPUE) ranges are given. (Mekkawy 1998).**

Fishing ground	No.	Effort range (boat)	CPUE range (ton/boat/month)	MSY (ton)	f_{MSY} (boat)
El Ramla*	1	86-120	0.45-1.18	+	+
Dihmit (east)	2	10-19	0.87-1.57	20.84	22
Dihmit (east)	3	13-49	0.89-1.52	60.35	97
Dihmit (west)	4	18-31	0.69-1.61	273.96	693
Amberkab (east)	5	13-17	0.39-1.71	13.52	16
Amberkab (east)	6	6-16	0.56-1.46	10.12	13
Amberkab (west)	7	2-12	0.12-0.99	4.85	9
Amberkab (west)	8	6-14	0.23-1.89	10.09	14
Rahma (east)	9	7-34	0.69-1.58	32.82	36
Rahma (east)	10	5-25	0.69-1.92	48.69	87
Kalabsha	11	18-31	0.41-1.93	17.09	33
Gazal (north)	12	11-34	0.23-1.44	31.72	62
Gazal (north)	13	11-40	0.36-1.71	45.75	95
Gazal (north) inter	14	12-30	0.40-1.86	25.32	50
Gazal (north)	15	6-37	0.22-1.05	38.97	96
Gazal (inter)	16	3-20	0.15-0.93	7.59	19
Kalabsha (south)	17	3-39	0.23-1.25	22.78	44
Gazal (south)	18	13-39	0.21-1.08	38.94	91
Merwaw (east)	19	7-24	0.57-2.00	20.28	20
Fallahin (west)	20	15-34	0.59-0.98	113.37	295
Merwaw (west)	21	7-17	0.44-1.96	23.70	11
Merwaw (west)	22	15-27	0.33-1.16	15.58	34
Merwaw (east)	23	19-27	0.56-1.25	24.07	48
Wadi Abyad (east)	24	20-29	0.40-1.11	38.74	124
Wadi Abyad (east)	25	14-31	0.43-1.42	119.82	237
Wadi Abyad	26	8-28	0.53-1.99	20.16	27
Wadi Abyad	27	21-29	0.55-1.55	28.58	19
Galal	28	8-25	0.36-1.59	23.36	34
Mariya	29	10-24	0.52-1.63	18.37	20
Garf Hussein (west)	30	12-38	0.54-1.41	152.26	267
Garf Hussein	31	11-70	0.47-1.19	957.35	344
Garf Hussein (west)	32	6-29	0.44-1.07	117.21	215
Gersha	33	9-28	0.66-2.92	22.93	18
Gersha (east)	34	5-30	0.36-2.05	17.86	17
Abesko (east)	35	5-29	0.74-1.65	23.64	36
Abesko (east)	36	21-32	0.66-2.62	33.29	11
Abu-Derwa (west)	37	17-30	0.59-9.42	23.00	20
Abu-Derwa (west)	38	21-42	0.40-1.36	42.10	59
Allaqi (north)	39	10-41	0.42-2.46	31.03	22
Allaqi (south)	40	7-26	0.53-1.86	25.75	45

***Data for Khor El Ramla are based on years 1991,1993, 1994; + means positive correlation between effort & CPUE.**

Table 158 **Estimation of maximum sustainable yield (MSY) per month and the related optimum effort (f_{MSY}) of the fishing grounds of the southern part of Lake Nasser based on the data of Mohamed, M. (1993a, b, 1995a, b) for 1988-1994. Monthly effort and catch per unit effort (CPUE) ranges are given. (Mekkawy 1998).**

Fishing ground	No.	Effort range (boat)	CPUE range (ton/boat/month)	MSY (ton)	f_{MSY} (boat)
Allaqi	41	2-30	0.47-2.27	16.18	23
Allaqi	42	10-24	0.83-3.97	36.53	20
Allaqi	43	13-24	0.57-2.44	30.48	27
Allaqi (east)	44	28-45	0.63-1.85	36.62	63
Korta (west)	45	9-28	0.67-1.54	404.36	840
Moharrka	46	9-31	0.89-1.44	60.87	99
Sayala (west)	47	9-31	0.72-2.93	26.73	24
Sayala (west)	48	18-39	0.34-1.69	27.5	36
Sayala (west)	49	15-26	0.47-1.52	31.67	50
Sayala (west)	50	17-27	0.37-2.71	55.5	95
Sayala (west-east)	51	11-25	0.57-2.61	23.21	14
Madiq (east)	52	12-25	0.44-1.44	15.57	20
Madlq (east-west)	53	28-37	0.32-2.07	47.69	74
El Soboui (east)	54	3-27	0.52-5.06	22.35	18
El Soboui (east-west)	55	12-22	0.40-2.15	45.41	22
Wadi El Arab	56	7-32	0.58-1.92	65.15	153
Malki-Singary	57	20-30	0.42-2.36	29.21	20
Malki	58	8-28	0.79-6.23	16.54	10
Korosko (east)	59	8-48	0.77-2.14	38.97	21
Korosko (inter)	60	9-22	0.43-3.92	27.95	12
Korosko	61	8-56	0.61-5.55	59.90	33
Abu Handal (east-west)	62	9-65	0.67-2.01	50.42	46
Abu Handal (east-west)	63	10-36	0.59-1.97	48.46	72
Thomas, Afia (east-west)	64	7-54	0.99-2.11	427.67	618
Ebrim Afia	65	5-35	0.56-2.72	41.19	46
Shebbak	66	9-51	0.70-3.83	50.90	53
Masmas (west)	67	11-36	0.56-2.49	40.87	40
Masmas (inter)	68	8-29	0.85-1.80	37.00	49
Tushka (west)	69	28-36	0.99-2.90	+	+
Tushka (west)	70	21-56	0.75-3.08	73.56	67
Tushka (west)	71	13-52	0.94-3.27	42.56	44
Tushka (west)	72	7-28	0.86-2.63	59.52	51
Forgondy (west)	73	5-20	0.85-2.68	+	+
Forgondy (west)	74	7-28	0.65-1.67	46.21	58
Hamido (east)	75	10-63	0.76-1.56	73.82	165
Hamido (east)	76	2-37	0.91-2.27	56.90	59
Khor-Bateakh	77	7-61	0.86-5.47	73.11	50
Abu Simbel (east)	78	3-25	0.33-1.15	35.99	14
Abu Simbel (west)	79	2-39	0.41-1.11	96.89	204

+ means positive correlation between effort & CPUE.

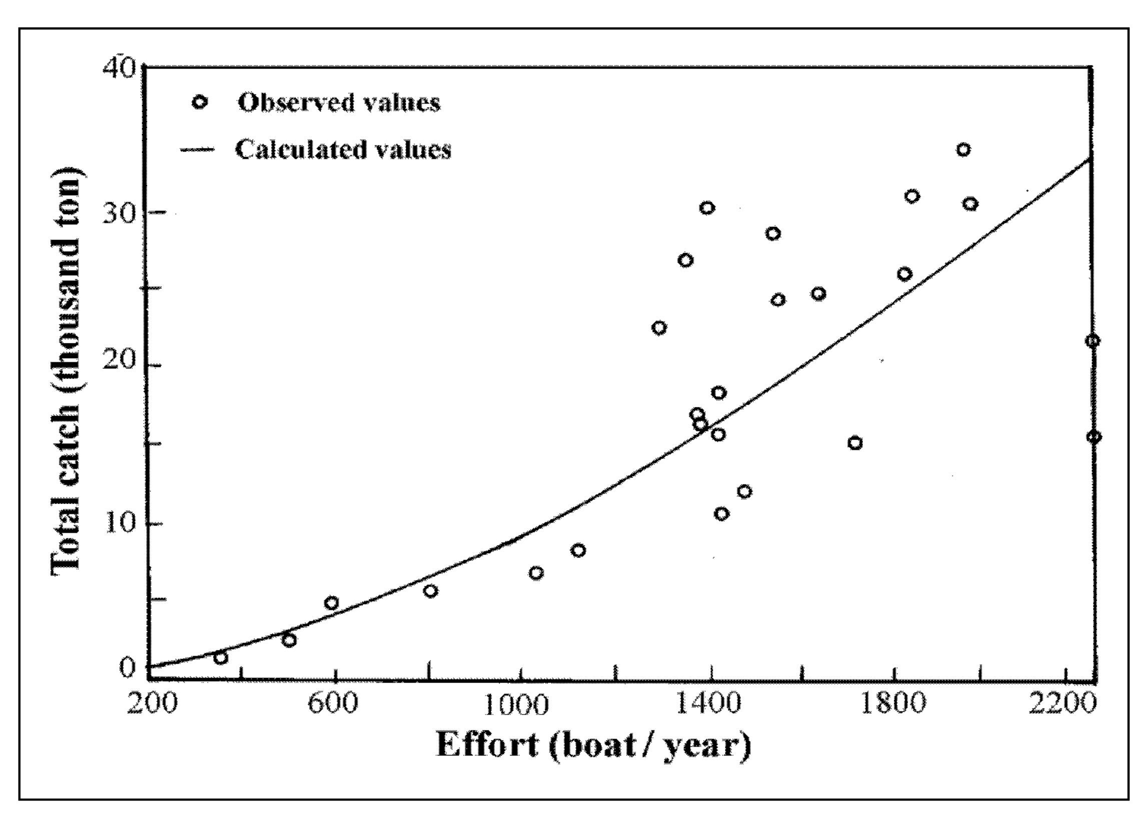


Fig. 222 Total catch-effort data of Lake Nasser for 1966-1992 period fitted to power function equation. (Mekkawy 1996).

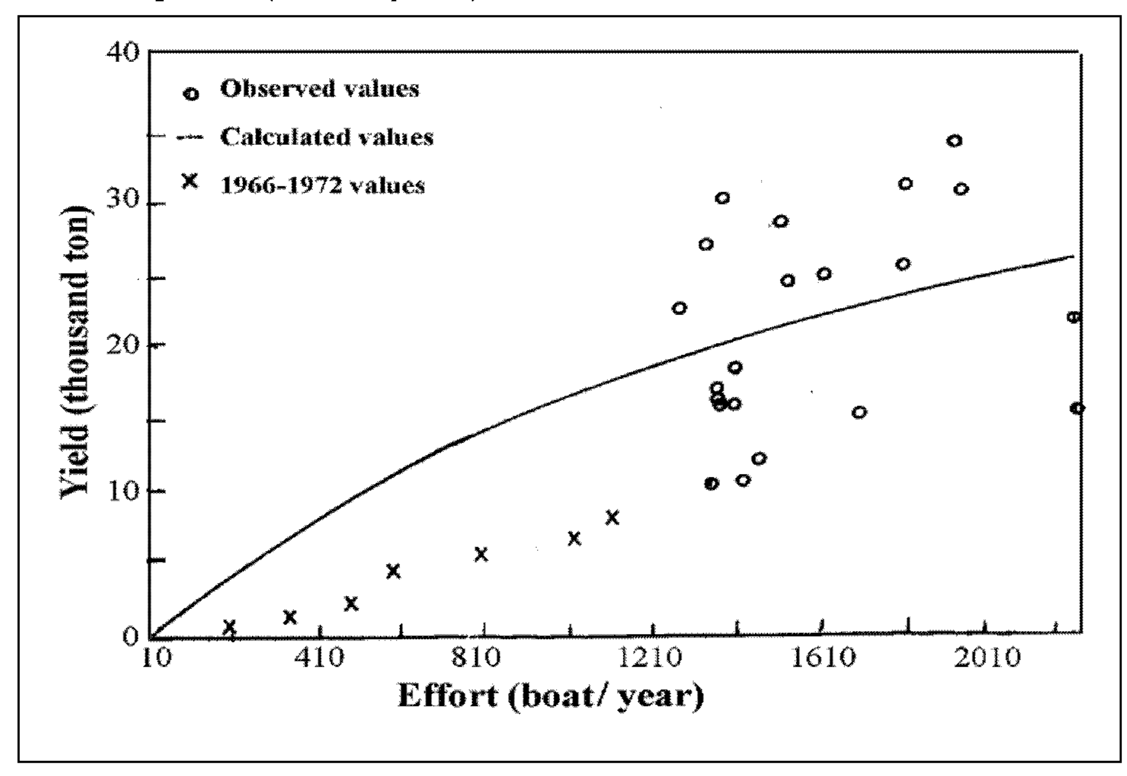


Fig. 223 Total catch-effort data of Lake Nasser for 1973-1992 fitted to the hyperbolic model 1966-1972 yield values were estimated according to such model (x) (Mekkawy 1996).

Catch (C) = 1.0 / (0.00002 + 0.04089/E)

Such a hyperbolic model determines (MSY) with infinite effort. The MSY (after its multiplication by 1.11233919 to convert from harmonic to arithmetic mean) was 55,616.69 ton.

Fig. 223 shows that the fitted data of the initial years of Lake formation (1966 -1972, denoted by x) were away of the corresponding expected values of the model used. Mekkawy (1998) found that it was impossible to fit data of the total period (1966-1992) to that model due to the negative values of the constant parameters which in turn were due to the increased CPUE of the initial years of Lake formation.

Since the CPUE of 1973-1992 for tilapiines and of 1966-1992 for other groups of fishes had undergone relatively substantial changes, the holistic model of Schaefer (1954), Schaefer's Model, was applied by Mekkawy (1998) and fitted to describe the CPUE-effort relationship of different fish groups of Lake Nasser. The parameter estimates of such a model and the corresponding MSY and f_{MSY} are given in Table 159 and Fig. 224.

$Y_{(i)}/f_{(i)} = a\ bf_{(i)}$ if $f_{(i)} \leq -a/b$

where, $Y_{(i)}$ = catch, $f_{(i)}$ = effort, a and b are constants.

$f_{(MSY)} = -0.5\ a/b$

$MSY = 0.25\ a^2/b$

***Table 159* Maximum sustainable yield (MSY) and the corresponding fishing effort [f_{MSY}] for fish groups of Lake Nasser (Mekkawy 1998).**

Species	a	b	f_{MSY} (boats)	MSY (ton)
***Tilapia* spp.**	12.3794	- 0.00068495	9037	55934.57
0. niloticus	7.15774	- 0.000396027	9037	32342.01
S. galilaeus	5.221626	- 0.000288916	903	23592.82
***Hydrocynus* spp.**	2.552008	-0.000484051	2636	3363.67
Lates niloticus	0.2807073	-1.322234	1061	1489.84
***Labeo* spp.**	1.297548	- 0.000656976	988	640.67
***Bagrus* spp.**	0.2201915	-0.000111074	991	109.13
***Clarias* spp.**	0.2113117	- 0.000104679	1009	106.64

a and b are constants.

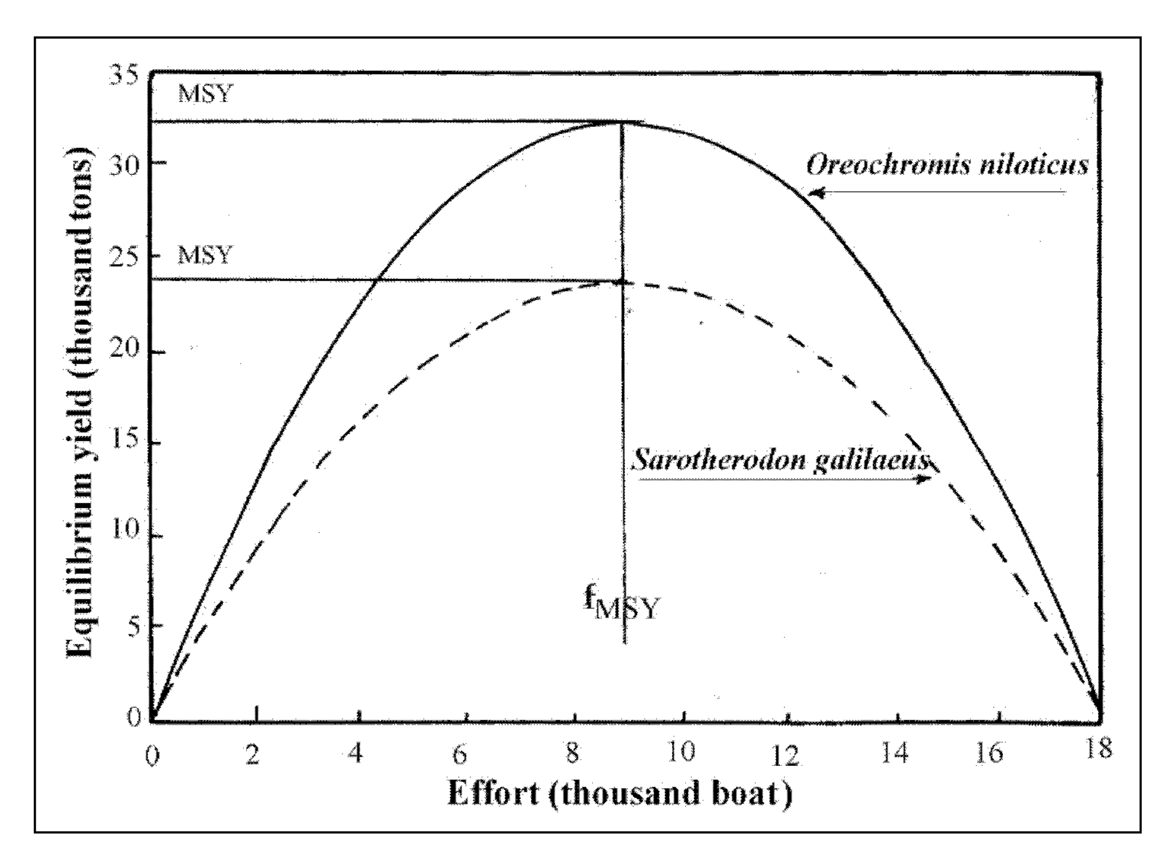


Fig. 224 **Equilibrium yield-effort relationships (Schaefer model) for *O.* niloticus *and S.galilaeus* of Lake Nasser (1973-1992) (Mekkawy 1998).**

Table 159 shows that the MSY for the tilapiines was found to be equal to both MSY for *O. niloticus* and *S. galilaeus*. The total MSY of the Lake was 61,644.78 ton, tilapiines MSY represented 90.74% of it (Table 159). The MSY's of other fish groups were low and reflected the severe condition that controlled their production (Mekkawy 1998).

Proposed modification of Schaefer's Model. One can take Lake area (A) in consideration due to its effect as spawning grounds on the catch. Therefore, Schaefer's Model and MSY can be written in the forms:

$$Y(i)/f_{(i)} * A_{(i)} = a + bf_{(i)}$$

$$MSY = (-0.25\ a^2/b) * A_{(i)}$$

where $A_{(i)}$ is the average Lake area in the six preceding years. In such a model, f_{MSY} is not affected by Lake area. Mekkawy (1998) fitted such a model to 1981- and 1989-total-catch-effort data, taking the effect of lake area (as spawning grounds) on the catch into consideration. The following equations were derived:

$$Y_{(i)}/\ f_{(i)} * A_{(i)} = 0.070079269 + -\ 2.669437\ E\text{-}05 * f_{(i)}$$

$$MSY = 45.993817\ A$$

Accordingly, the total MSY of the Lake with maximum area of 1,250,000 feddans (505868 ha) was estimated to be 57,492.27 ton with f_{MSY} =1313 boats. Since the average tilapia catch of 1991-1992 represented 93.5% of the total catch, the tilapiine MSY can be estimated to be 53,755.27 ton (Mekkawy 1998).

Estimation of maximum sustainable yield (MSY) using Graham's Model in relation to biomass

According to Ricker (1975), Mekkawy (1998) fitted a Graham curve from the relation of surplus production to biomass, to catch-effort data of *O. niloticus* and *S. galilaeus* using the formula:

$Y_E/B=k-(k/B_\infty)*B$ ...... (Ricker 1975)

where, Y_E is the yield when the stock is in equilibrium, B is the mean stock biomass. B_∞ is the maximum stock size and k is a constant

The results (Table 160) show that the MSY of the two tilapiine species (54,107.07 ton) was nearly similar to that determined by Schaefer's Model, while f_{MSY} was different. Since the average tilapiine catch of the years 1991-1992 represented 93.5% of the total catch, the total MSY can be estimated to be 57,868.52 ton (Mekkawy 1998).

Table 160 **Results of fitting Graham's curve to catch-effort data of *0. niloticus* and S. *galilaeus* in relation to their biomass (Mekkawy 1998).**

Parameter	*O. niloticus*	*S. galilaeus*
Intercept (K)	1.40544	2.51893
Slope ($-K/B_\infty$)	-1.838254 E-05	-5.822434E-05
Maximum stock size (B_∞)	76455.16	43262.49
Optimum stock size (Bs)	38227.57	21631.25
Maximum sustainable yield (ton)	26863.28	27243.79
Optimum fishing effort (f_{MSY})	937	910
Fishing mortality rate (F)	0.70272	1.259465
Catchability coefficient (q)	7.2188706 E-04	1.3835616 E-03

Estimation of maximum sustainable yield (MSY) using Surplus Production Model

Mekkawy (1998) calculated the catchability coefficient (q) of *0. niloticus* and *S. galilaeus* (Table 160) using the natural death rate (Z) and Silliman's Method (Ricker, 1975). The latter author also calculated the surplus biomass production and consequently the parameters recorded in Table 160. Mekkawy (1998) used the following equation:

$Y_E/\overline{B} = k - (k/B_\infty)\,\overline{B}$ .... Ricker (1975)

where Y_E = surplus production, $\overline{B}$ = mean stock size

B_∞ = maximum stock size, k = constant

Figs. 225 and 226 explain the surplus production / biomass and biomass relationships of *O. niloticus* and *S. galilaeus*.

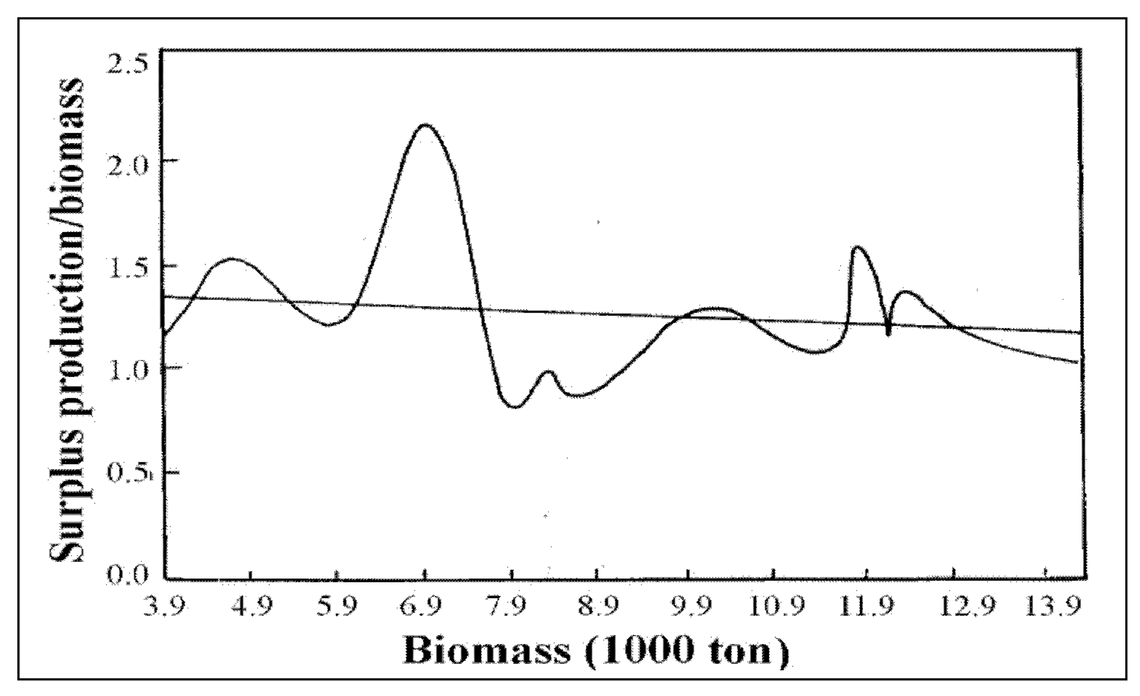


Fig. *225* **Surplus production/biomass-biomass relationship of *Oreochromis niloticus* of LakeNasser (1973-1992) (Mekkawy 1998).**

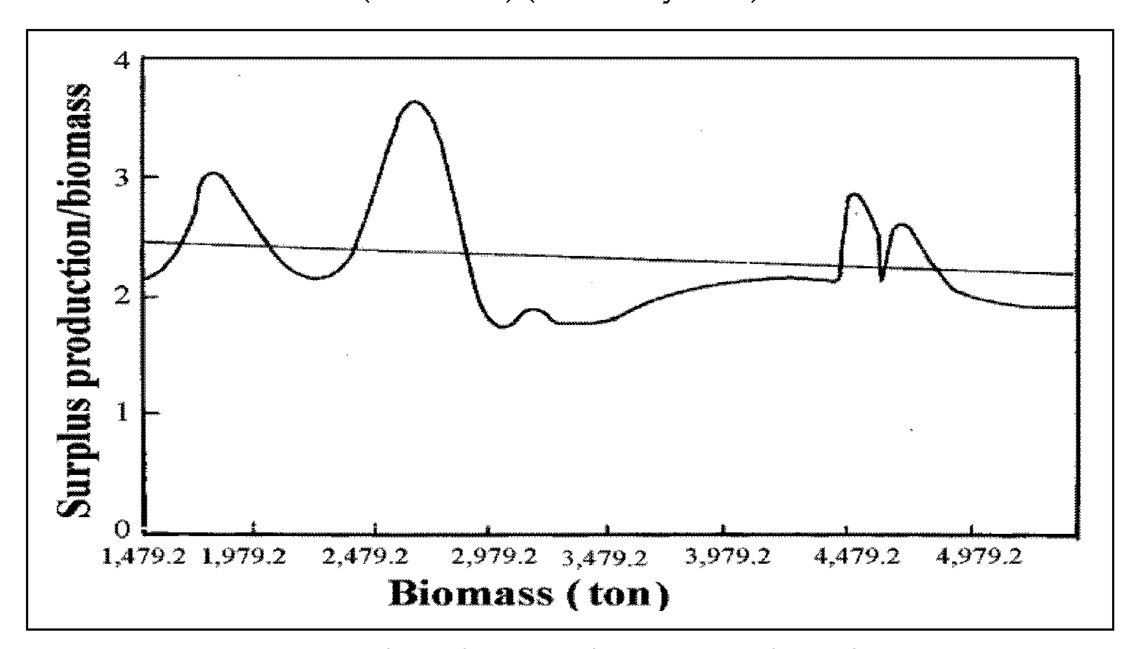


Fig. *226* **Surplus production/biomass-biomass relationship of *Sarotherodon galilaeus* of Lake Nasser (1973-1992) (Mekkawy 1998).**

Estimation of maximum sustainable yield (MSY) using the Generalized Stock Production Model (Fox 1975)

Fox (1975) mentioned that catch-effort data usually do not represent equilibrium conditions. Accordingly, catch-effort data of Lake Nasser were adjusted to approximate these conditions, and hence the Generalized Stock Production Model of Fox (1975) was fitted (Mekkawy 1998). The results of fitting the aforementioned model to catch data of *O. niloticus* and *S. galilaeus* are presented in Table 161 and Figs. 227 and 228. The catchability coefficients of both tilapiine species estimated by the Generalized Stock Production Model are shown in Table 162. MSY was estimated to be 25,336.9; 15,614.1 and 15,347.5 ton for *O. niloticus* and to be 32,970.0; 16,542.7 and 13,657.7 ton for *S. galilaeus* according to Asymptotic, Gompertz and Logistic Models respectively (Mekkawy 1998). The latter author mentioned that except for those estimated by Asymptotic Model, the other MSY's in comparison with the above estimated ones showed considerable variations and were underestimated. Mekkawy (1998) estimated the total MSY of Lake Nasser to be 62,360.32 ton according to the Asymptotic Model considering the average percentage of tilapiine catch during 1991-1992 (93.5%).

Estimation of maximum sustainable yield (MSY) using age-based Thompson & Bell Model

Mekkawy (1998) calculated the yield, value of yield and biomass of *O. niloticus* and *S. galilaeus* by the age based Thompson & Bell Model (Sparre *et al.* 1992). Figs. 229 and 230 show the yield, economic value of the yield and biomass curves of these species. MSY's of *O. niloticus* and S. *galilaeus* were 30,127.64 and 17,692.34 ton at a multiplication factor of 1.7 and 0.48 respectively. This means that the 1979-cohort fishing pattern should be highly increased to obtain MSY of *O. niloticus* and be decreased to achieve MSY of *S. galilaeus.* When the price per kilogram is 2 LE, (the fixed price by the authorities; the market price is not less than 9 L.E/kg) the maximum sustainable economic yield value (MSE) will be 60,254,380 LE and 35,384,670 LE for *O. niloticus* and *S. galilaeus* respectively (Mekkawy 1998 Figs. 229 and 230).

Table 161 **Results of fitting Generalized Stock Production Model (Fox, 1975) to catch data of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser for 1966-1992. (Mekkawy 1998).**

Parameter	*Oreochromis niloticus*			*Sarotherodon galilaeus*		
	M*=			M*=		
	0	1	2	0	1	2
Pre-exploitation catch/effort	16.09	13.07	11.34	7.92	7.53	7.28
Optimum catch/effort		4.81	5.67	--	2.74	3.64
Optimum fishing effort	--	3245	2706	--	6030	3751
Maximum sustainable yield (ton)	25336.9	15614.1	15347.5	32970.0	16542.7	13657.7
By geometric mean						
Virgin population size (ton)	194019	130531	110722	159916	135870	115951
Optimum population size (ton)	--	48043.8	55361.0	--	50008.8	57975.7
By arithmetic mean						
Virgin population size (ton)	79947.5	60636.7	51673.1	75152.5	67596.9	57901.1
Optimum population size (ton)	--	22318.1	25836.5	--	24879.9	28950.5

*** M =0, according to the Asymptotic Yield Model. M =1, according to the Gompertz Model, M =2, according to the Logistic ModeL**

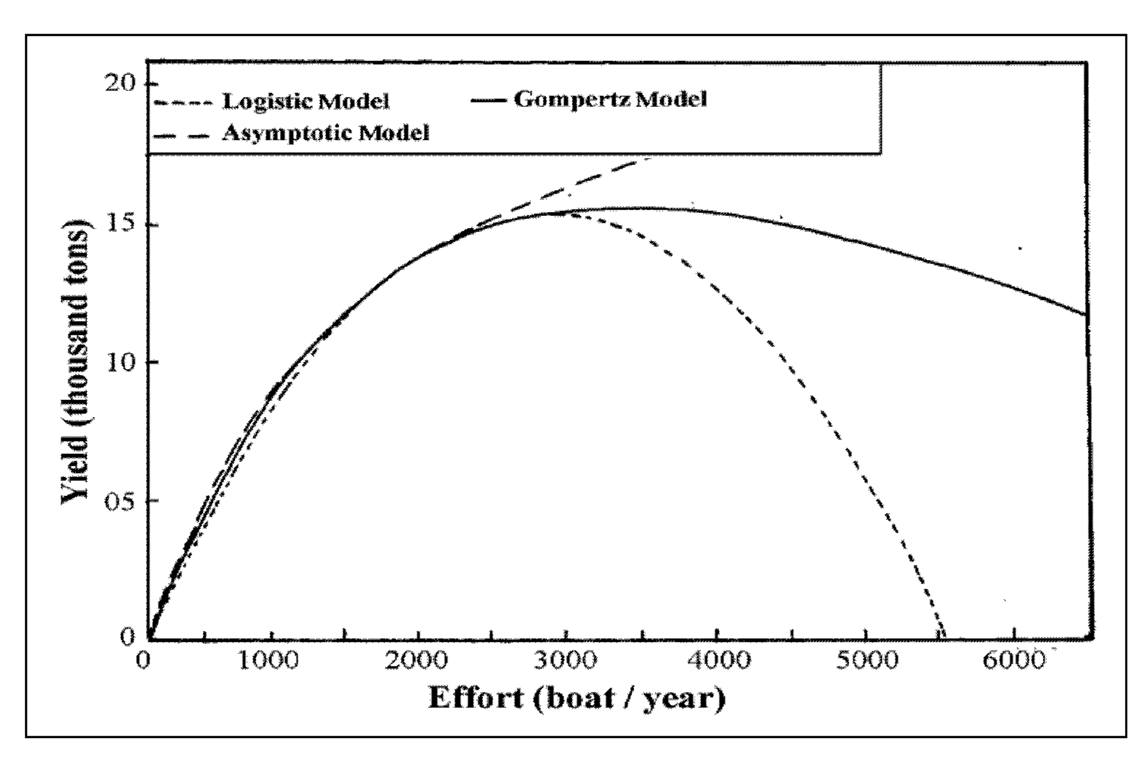


Fig. 227 Catch-effort data of *Oreochromis niloticus* of Lake Nasser for 1966-1992 fitted to the Generalized Stock Production Model* (Mekkawy 1998).

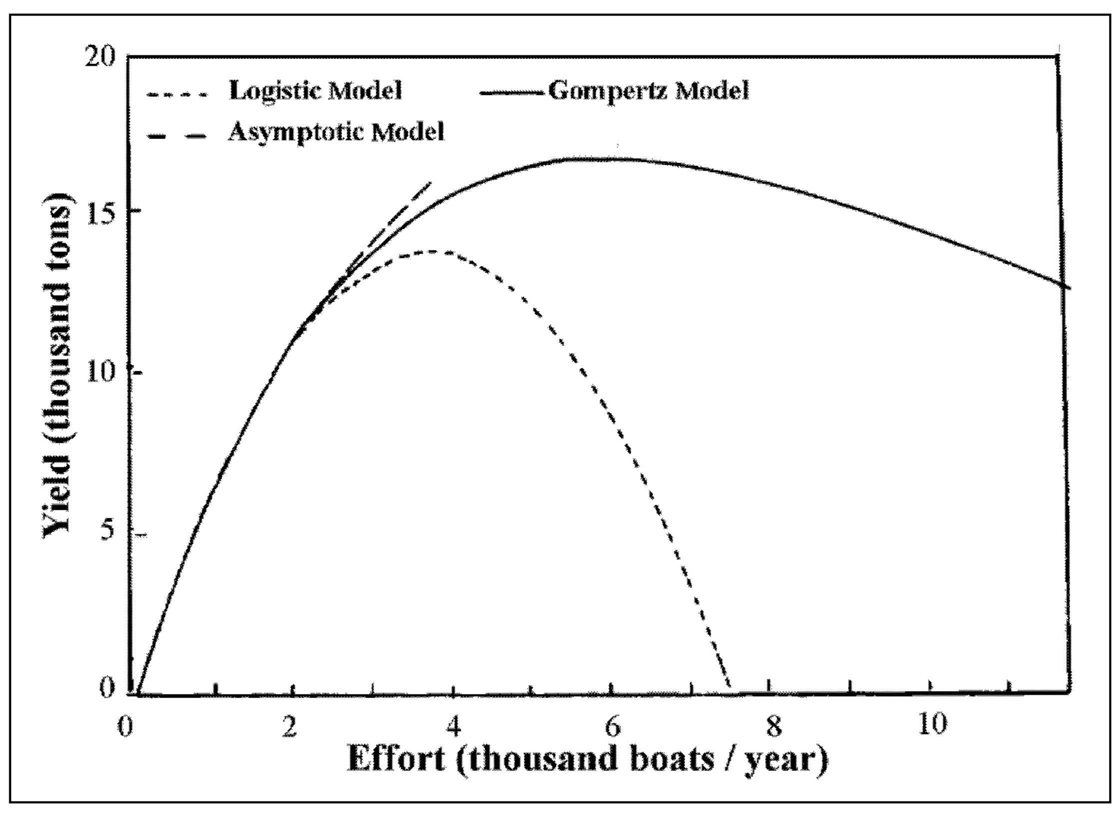


Fig. 228 Catch-effort data of *Sarotherodon galilaeus* of Lake Nasser for 1966-1992 fitted to the Generalized Stock Production Model* (Mekkawy 1998).

*(Fox 1975)

Table 162 **Catchability coefficients of *Oreochromis niloticus* and *Sarotherodon galilaeus* of Lake Nasser estimated by the Generalized Stock Production Model** (Mekkawy 1998).**

Years	Catchability coefficient					
	Oreochromis niloticus			*Sarotherodon galilaeus*		
	M*=			M*=		
	0	1	2	0	1	2
1973 & 1974	0.342721E-05	0.578748E-05	0.780571E-05	0.196079E-05	0.322847E-05	0.518372E-05
1974 & 1975	0.259511E-04	0.490654E-04	0.575256E-04	0.146985E-04	0.235925E-04	0.374827E-04
1975 & 1976	0.747395E-04	0.109466E-03	0.136376E-03	0.426454E-04	0.605548E-04	0.876032E-04
1976 & 1977	0.226919E-04	0.298569E-04	0.335309E-04	0.133309E-04	0.171691E-04	0.227856E-04
1977 & 1978	0.435108E-03	0.473898E-03	0.464885E-03	0.297584E-03	0.318066E-303	0.353474E-03
1978 & 1979	0.178489E-03	0.170935E-03	0.104870E-03	0.855421E-04	0.703247E-04	0.442098E-04
1979 & 1980	0.239989E-03	0.200931E-03	0.139865E-03	0.974938E-04	0.803967E-04	0.729503E-04
1980 & 1981	0.244411E-03	0.224022E-03	0.181249E-03	0.134481E-03	0.117625E0303	0.110824E-03
1981 & 1982	0.288206E-04	0.276371E-04	0.239768E-04	0.168248E-04	0.153623E-04	0.150980E-04
1982 & 1983	0.842603E-05	0.807143E-05	0.692804E-05	0.465112E-05	0.423564E-05	0.417849E-05
1983 & 1984	0.119790E-03	0.116328E-03	0.102207E-03	0.662916E-04	0.610731E-04	0.611060E-04
1984 & 1985	0.310136E-03	0.308226E-03	0.267033E-03	0.119256E-03	0.109431E-03	0.113531E-03
1985 & 1986	0.119623E-02	0.117835E-02	0.120476E-02	0.406355E-03	0.392886E-03	0.437950E-03
1986 & 1987	0.218525E-04	0.239755E-04	0.234119E-04	0.139633E-04	0.150766E-04	0.170181E-04
1987 & 1988	0.372923E-04	0.417163E-04	0.413309E-04	0.234248E-04	0.257679E-04	0.296414E-04
1988 & 1989	0.254674E-03	0.342742E-03	0.386160E-03	0.139413E-03	0.178973E-03	0.241897E-03
1989 & 1990	0.187736E-03	0.288424E-03	0.356481E-03	0.943128E-04	0.131544E-03	0.195688E-03
1990 & 1991	0.240750E-04	0.902049E-04	0.202893E-03	0.766035E-04	0.122068E-03	0.180329E-03
1991 & 1992	0.409764E-03	0.413130E-03	0.432860E-03	0.354375E-03	0.347695E-03	0.358573E-03

***M = 0, according to the Asymptotic Yield Model; M=1, according to the Gompertz Model; M=2 according to the Logistic Model.**

**** (Fox 1975).**

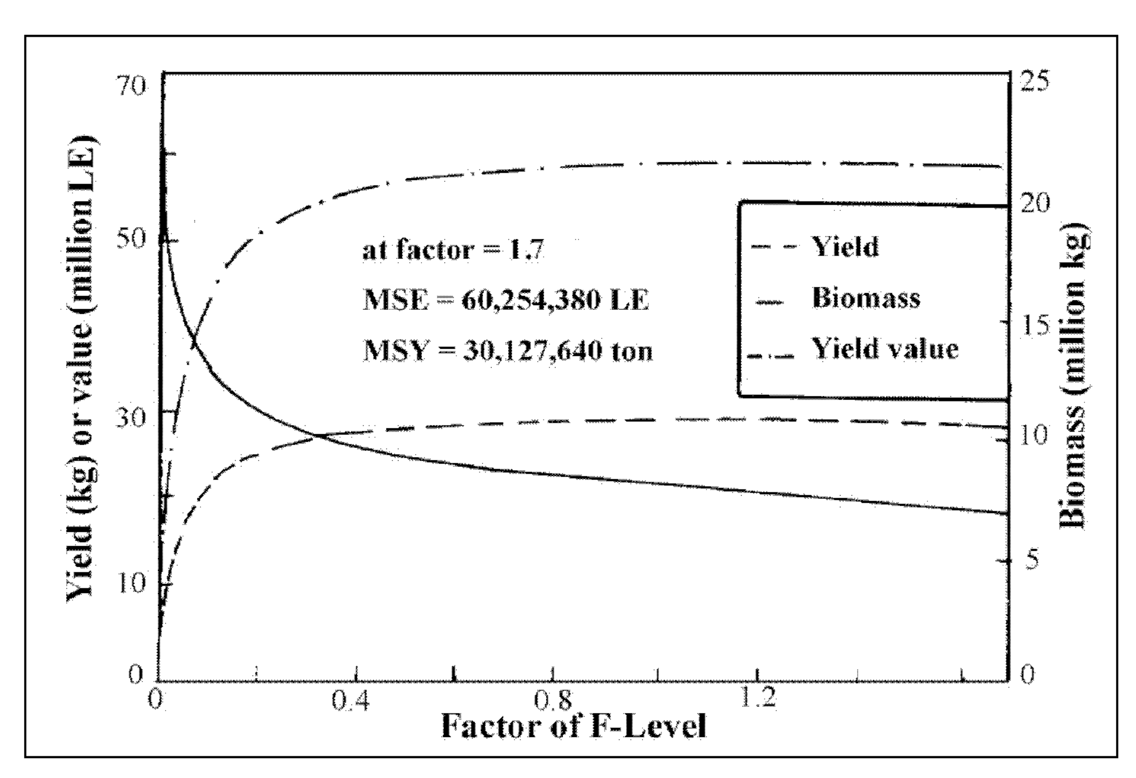


Fig. 229 **Yield, value of yield and biomass of *Oreochromis niloticus* calculated by the age based Thompson & Bell Model (Sparre *et al.* 1992) (MSY = Maximum Sustainable Yield, MSE = Maximum Sustainable Economic Yield (value) (Mekkawy 1998).**

Table 163. **Maximum Sustainable Yield (MSY) of tilapiine spp. *(0. niloticus* and *S. galilaeus)* from Lake Nasser, estimated by Mekkawy (1998) using various methods.**

Method of estimating MSY	MSY of tilapiine spp. (ton)		
	O. niloticus	*S. galilaeus*	Total
Schaefer's Model	32,342.01	23,592.82	55,934.83
Proposed modification of: Schaefer's Model	-	-	53.755.27
Graham's Model	26,863.28	27,243.79	54,107.07
Generalized Stock Production Model:			
Asymptotic Yield Model	25,336.9	32,970.0	58,306.9
Gompertz Model	15,614.1	16,542.7	32,156.8
Logistic Model	15,347.5	13,657.7	29,005.2
Age-based Thompson & Bell Model	30,127.64	17,692.34	47,819.98

A comparison between the maximum sustainable yield (MSY) of tilapiine spp. *(O. niloticus* and *S. galilaeus)* from Lake Nasser, estimated by different methods is given in Table 163. The highest MSY of tilapiine spp is 58,306.9 ton and is obtained by using the Generalized Stock Production Model "Asymptotic Yield Model"; while the lowest one (29,005.2 ton) is obtained by using the Logistic Model. It is obvious that the possible maximum sustainable yield of tilapiine spp. from Lake Nasser is around 55,000 ton.

ESTIMATION OF FOOD QUANTITIES REQUIRED TO OBTAIN MAXIMUM SUSTAINABLE YIELD (MSY)

Lake Nasser fishes belong to different trophic levels (Latif 1984a, Rashid 1995). *Brycinus nurse, Alestes baremoze, A. dentex, Labeo coubie, L.horie, L.niloticus, L. victorianus* and *Tilapia zillii* are primary consumers feeding on bottom deposits, filamentous algae and higher plants. *Synodontis schall, S. clarias, S. serratus, Mormyrus kannume, M. caschive, Chrysichthys auratus* and *C. rueppelli* are secondary consumers feeding mainly on insect larvae, molluscs and crustaceans. *Hydrocynus forskalii, Bagrus bajad, B. docmak, Schilbe mystus, Schilbe (Eutropius) niloticus* and *Lates niloticus* are tertiary consumers (mainly piscivores). *O. niloticus* and *S. galilaeus* can be identified as bacterial, phytoplankton filter and plankton feeders, these fishes can be considered predator fishes on rotifers, copepods and ostracods. Therefore, we can say that *O. niloticus* and *S. galilaeus* feed at more than one trophic level. In his work, Mekkawy (1998) analyzing the commercial catch, as a function of abundance, refers to the fact that Lake Nasser ecosystem is in favour of those species exhibiting more flexibility in their diets, which may cross trophic level boundaries, viz., *O. niloticus* and *S. galilaeus.* Economically, the dominance and increased abundance of both tilapiine species is considered more suitable because they can use 10% of the available potential energy, the other species of higher trophic levels use only 1% of such energy. A fishery based on herbivorous fish will therefore be more productive than one based mainly on predators.

Mekkawy (1998) mentioned that in later years, the herbivorous *Tilapia zillii* spread in Lake Nasser. Hickling (1961) recorded that *T. zillii* plays a multiple role as a plant feeder by making nutrient material available for plankton or making its faecal masses available for other fishes. The latter author pointed out that the ability of such species to bring back into circulation the plankton nutrients locked up in tissues of water plants has led to successful introduction of that species in Lake Victoria. Further studies on the biology of *T. zillii* and its impacts on Lake Nasser ecosystem should be carried out in the near future. Also, it is required to investigate the trophic level interactions and to determine food requirements for different species inhabiting Lake Nasser.

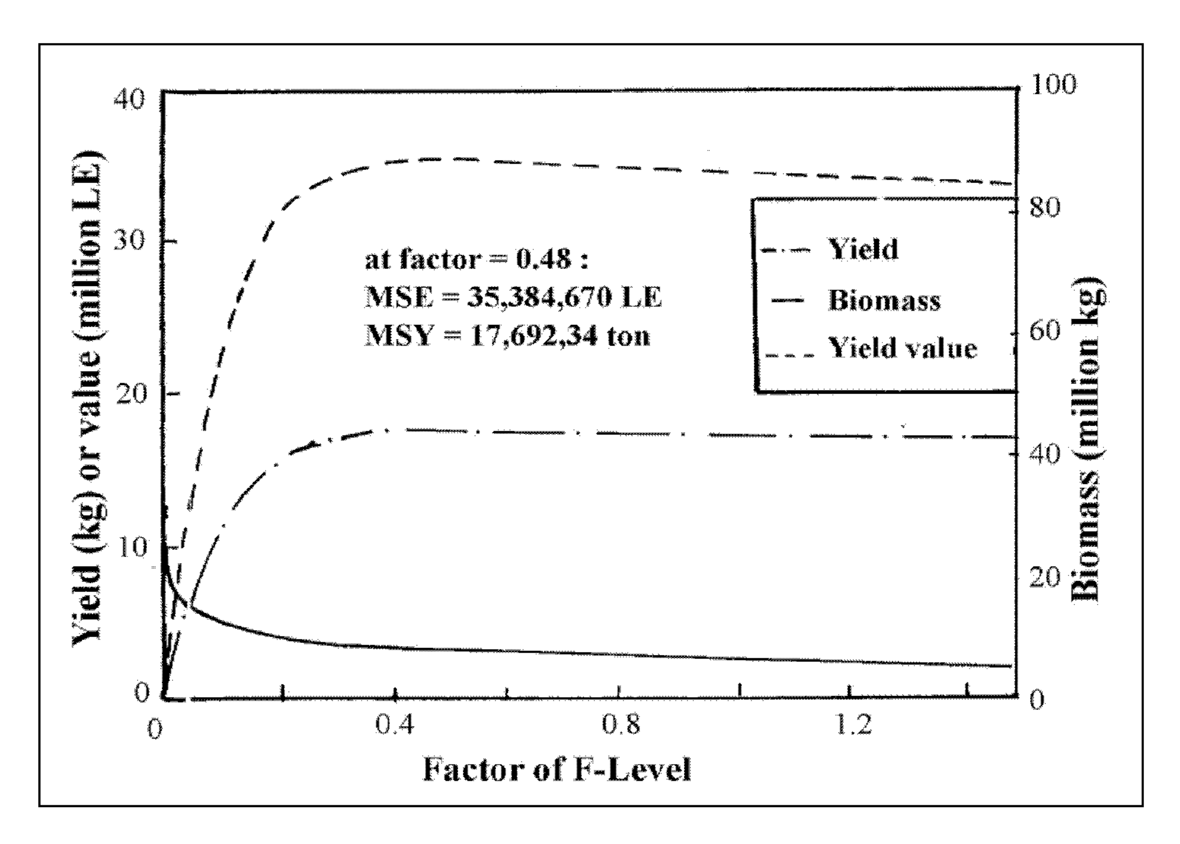


Fig. 230 **Yield, value of yield and biomass of *Sarotherodon galilaeus* calculated by the age based Thompson & Bell Model (Sparre *et al.* 1992) (MSY = Maximum Sustainable Yield, MSE = Maximum Sustainable Economic Yield value) (Mekkawy 1998).**

The relationship between feeding rates and growth has been investigated by several authors including Ivlev (1961) and Winberg (1960) using predator oriented approach. Conover (1978) studied the feeding rate in relation to body size and temperature. According to Ssentongo & Welcomme (1985), Conover's study leads to two main conclusions: an increase in water temperature increases the feeding rate, and small fish require a bigger ration under given conditions than larger fish. Caddy (1983) has examined series of data from Conover (1978) for a range of bottom dwelling fish and established the following relationship:

$$\ln (r_{T,W}) = 1.841 - 0.286 \ln (W) + 0.048T$$

where $(r_{T,W})$ is the feeding rate (as a percent of body weight per day), W is the mean body weight in gram and T is the mean water temperature.

Using Caddy's (1983) equation, Ssentongo & Welcomme (1985) determined the food requirements to obtain MSY of *Lates niloticus* in Lake Victoria. Accordingly, such equation can be applied to Lake Nasser fish species and hence their food requirements to obtain the maximum sustainable yield.

Mekkawy (1998) determined the food requirements for *O. niloticus* in Lake Nasser. According to Mekkawy *et al.* (1994), the mean weights (W) of *O. niloticus*

caught in trammel nets are 33 ; 290 and 801 g for length groups (standard length) 30-90, 91-200 and 201-450 mm respectively. The mean ambient temperature of Lake Nasser is 22 °C. Using Caddy's equation, Mekkawy (1998) determined the feeding rates of *O. niloticus* as 6.67, 3.58 and 2.68 % for length groups 30-90, 91-200, 201-450 mm respectively. The latter author determined the total annual food (X) required to obtain the mean MSY of *O. niloticus* (30,000 ton) using Caddy's (1983) estimator.

$$X=365(r_{T,W})B/100$$

where B is the mean biomass which can be derived from the following equation, the generalized version of Gulland's estimator proposed by Cadima (Troadec 1979):

$$MSY=0.5ZB$$

where Z = 1.95, the total mortality of year 1992. B was estimated to be 30,769.23 ton. This value was distributed for the three length groups of *O. niloticus* by percentages derived from Abdel-Azim (199la) and Mekkawy *et al.* (1994). Table 164 shows the annual food required to obtain maximum sustainable yield (30,000 ton) of *O. niloticus* from Lake Nasser.

***Table 164* Annual food (ton) required to obtain the maximum sustainable yield (30,000 ton) of *Oreochromis niloticus* of Lake Nasser according to length groups (based on data by Abdel-Azim (1991a), Mekkawy *et al.* (1994) and Mekkawy (1998).**

Food item	**Length group (standard length) in mm**		
	30-90	**91-200**	**201-450**
Cyanophyta	8373.06	48670.94	101043.82
Chlorophyta	7433.03	33329.01	45632.58
Diatoms	16572.63	46188.20	24907.88
Higher plant tissue	-	1689.19	7004.40
Plant detritus	473.44	3434.07	2395.18
Animal detritus	29.22	232.03	778.27
Copepoda	-	-	3478.72
Cladocera	-	412.55	975.18
Rotifera	200.88	1213.99	108.69
Inorganic particles	27.39	83.53	100.64
Total (ton)	**33,109.65**	**135,253.51**	**186,425.36**
Fish biomass (ton)	1359.99	10350.77	19058.46
%	4.42	33.64	61.94
Fish abundance (No.)	41,846,154	35,692,308	23,793,335
%	41.30	35.22	23.48
Average weight (g)*	33	290	801
Total length (mm)	50-130	131-260	261-570
Feeding rate (%)	6.67	3.58	2.68

***As previously mentioned (pp 257 & 258) the average weights given by Mekkawy *et al.*, (1994) are much lower than the actual weights recorded during recent years.**

CONCLUSIONS

Assessment of Lake Nasser fisheries is required for better development and management of the resources on which the fishery is based. This requires a certain preliminary assessment of the level of exploitation of the fishery relative to its potential. Furthermore, details of the biological and ecological constraints to the resource are needed for the effective management and monitoring.

Lake Nasser is almost lacustrine except in its southernmost part (about 50 km in length), which has riverine characteristics during the flood season. The number of important khors in Lake Nasser is 85, of which 48 are located on the eastern side and 37 on the western side. Lake Nasser is eutrophic in some areas (khors), while it is mesotrophic to oligotrophic in other parts (main channel, which constitutes 80% of the total area of the Lake proper).

As a matter of fact, remarkable changes both in environment and fishery have been occurring in Lake Nasser since the construction of the High Dam. The knowledge of all the changes in surface area and volume of water in the khors at different water levels is very important for fish stock assessment and fishery development. The length of the shoreline and its slope are important factors for the development of periphyton and littoral fauna, the main food of *Tilapia* species, as well as the littoral areas provide tilapias with suitable breeding and nursery grounds.

Unfortunately, there is a lack of adequate knowledge on the present fish stocks, under the changing environmental conditions. Lake Nasser was originally a multispecies fishery during the first period of impoundment (1966-1975). Fifty six fish species belonging to 15 families were recorded. The most common open water species were *Alestes* spp., *Hydrocynus forskalii* and *Schilbe niloticus. Sarotherodon galilaeus, Oreochromis niloticus, Brycinus nurse, Hydrocynus forskalii* and *Lates niloticus* were abundant in inshore waters. At present, fish stocks are dominated by S. *galilaeus* and O. *niloticus.* The remaining fish species have either declined to insignificant levels or are almost in their way to disappear from the Lake. There has been no continuous information on the fish stocks in offshore and inshore waters of the Lake. Recently, Mekkawy (1998) carried out a study on fish stock assessment of Lake Nasser, with emphasis on those of O. *niloticus* and S. *galilaeus.*

Fishes are usually landed either fresh or salted. The predominant marketable fresh fishes are *S. galilaeus, O. niloticus, Lates niloticus, Labeo* spp., *Bagrus* spp. and *Synodontis* spp., while the salted fishes are mostly *Hydrocynus forskalii, Alestes* spp. and *Schilbe (Eutropius) niloticus.* The salted fish composed a high percentage of the total landed fish, with an average of 51.8% during 1966-1968. Then they decreased progressively to an average of 32.7% during 1969-1978, and to about 10.3% during 1979-1998.

Commercial fishes are classified according to their feeding habits into:

a- Periphyton-plankton feeders *(S. galilaeus* and *O. niloticus)*

b- Zooplankton-insect feeders *(Alestes* spp.)

c- Omnivorous fish, feeding mostly from the bottom and or between stones *(Barbus* sp., *Labeo* spp., synodontids, schilbeids and mormyrids).

d- Carnivorous fish (*Bagrus* spp., *Lates niloticus, Hydrocynus* spp., *Clarias* spp. and *Heterobranchus* spp).

The composition of fish landings is in favour of periphyton plankton feeders being about 90-93% of the total landings by weight during recent years.

The evolution and trends of the total fish catch and the catches of different fish groups in the percentage of the total fish catch during 1966-1996 are presented.

The total fish catch per month in spring is almost twice that in summer in both northern and southern regions of the Lake. However, in spring the total catch of the southern region reached about 1.5 times that of the northern region of the Lake.

Certain correlations between the catch of the major fish group *(Tilapia* spp.) and those of other fish groups in Lake Nasser are calculated. The intercorrelation matrix of the annual catch of different fish species is presented.

The significance trend analysis parameters of different fish groups catch through 1966-1994 and the trend analysis parameters of the catch of different khors fishing groups through August and December of 1988-1992 are calculated.

Tilapia species production may affect the production of other fish species. Thus, the catch of *Hydrocynus forskalii* and *Lates niloticus* may be affected by *Tilapia* species catch when it is more than 15,000 ton of annual catch, leading to a decrease in the annual production of the former two species. The catch of *Labeo* species and *Bagrus* species show a decrease, when *Tilapia* species catch is more than 10,000 and 5,000 ton respectively.

Highest fish yields were recorded in the southern region of the Lake, particularly close to Allaqi, Korosko and Tushka, where higher mean annual values of chlorophyll *a* and zooplankton were recorded. This phenomenon suggests the possibility of developing active fisheries in the southern region of Lake Nasser.

The fish species composition of experimental catches, using floating and sinking gill nets, is presented.

Tilapia spp. catch correlated significantly with water level during preceding years (from two to six years before the catch). There was no correlation between *Tilapia* spp. catch and the catch effort. The total catch of fishes from Lake Nasser correlated with previous water levels from two to six years, and this reflected the trend in case of *Tilapia* spp. catches, the major commercial species in the Lake.

The number of fishing boats used in Lake Nasser began with 200 in 1966, and gradually increased to 1700 in 1978, while from 1979 to 1989 it gradually decreased from 1613 to 1175. Then the number of fishing boats was stable (about 1900) during the period from 1990 to 1991 and increased to 2200 since 1994.

A relationship exists between the total annual fish production of the Lake and water level, which shows remarkable fluctuations from year to year. In 1966, the total landings was 751 ton, increased to 16,000 ton in 1976 due to the increase of water level and number of fishing boats. During 1976-1981, when the mean water level attained about 174 m, and the fishing effort was constant (1600 fishing boat), the total catch increased to 34,000 ton in 1981. The water level was relatively high and so very suitable for tilapia production. An exceptional negative correlation between water level and tilapiine catch, which represents about 90 % of the total fish catch was noticed during 1991 - 1999. Thus, tha mean water level increased progressively from 165.79 m in 1991 to 178.92 m in 1999, while simultaneously tilapiine catch decreased sharply from 29,383 ton in 1991 to 8606 ton in 1999. This is mainly attributed to that, a large portion of the catch is sold illegally in the black market with high prices, and hence not recorded in the official catches which do not represent the true tilapiine production from the Lake. Generally, the fish production in Lake Nasser is affected by many factors including prohibiting of fishing from 15th March to 15th May, which was enforced since 1990.

The relations between the catches (i.e. total, *Tilapia, Hydrocynus, Lates* and *Bagrus* spp.) and water level and effort are calculated by using multiple linear regression. The obtained picture makes it possible to predict the possible catch if knowing the water level and catch effort. Not all fish species are equally affected with water level or catch effort. Some of them are affected in some years with water level. In Lake Nasser *Tilapia* spp. are mostly affected with the fluctuations of water level, and this is reflected on the size of the total catch.

The monthly catch of both tilapiine species exhibited two or three major peaks. Also, the monthly variations of gonad index of *O. niloticus* and *S. galilaeus* show two major peaks. However, the catch peaks do not coincide with those of gonad index.

The fishing gears and nets used in Lake Nasser are: floating gill-nets, trammel nets, sunken gill nets, beach seines and long-line. Mesh selectivities of

trammel net for *O. niloticus* and *S. galilaeus* were determined experimentally.

The effort-biomass relationships for *O. niloticus* and *S. galilaeus* were described. Fishing cannot be considered the only factor that controls biomass. Fishing represents only 33 and 44% of the total effect for *O. niloticus* and *S. galilaeus* respectively.

Virtual Population Analysis (VPA) looks at the populations of *0. niloticus* and *S. galilaeus* in a historic perspective. The trend of increase in the yield, abundance and biomass per hectare are presented. The fish productions of both tilapiine species were determined. The ratio of production to biomass (turnover ratio) was relatively high in the first years of Lake impoundment. The Lake yield of tilapiines was lower than the biomass during 1966-1991, which means that their fisheries did not experience difficulties due to the increasing effort. However, in 1992, the biomass of both species slightly differed from the yield, which means the start of such difficulties. Hence, the fisheries of tilapiine species should be carefully monitored because higher fishing efforts together with a further series of droughts could bring ruin to these fisheries.

Trawl selection curves derived from VPA of *O. niloticus* and *S. galilaeus* as a function of body length are presented.

There are different growth patterns of *O. niloticus* and *S. galilaeus* during the period 1970-1990. Generally, the maximum length estimated for the two tilapiine species exhibited a decrease trend with the progression of years. Other population characteristics of *0. niloticus, S. galilaeus* and *L. niloticus* are presented.

The survivorship curves of 1979-cohorts of the two tilapiine species exhibited two different curves. According to Krebs (1985), type I curve represents populations with very little loss for most of the life span and then high losses of older organisms, whereas type II curve implies a constant rate of mortality independent of age. The survivorship curve of *0. niloticus* occupies an intermediate position between type I and type II curves of Krebs (1985), while that of *S. galilaeus* was close to type I curve.

Higher values of catch per unit effort, CPUE (more than 2 ton/boat/ month) are recorded from the fishing grounds located in the southern region of the Lake. The average value of CPUE in the southern region (i.e. 1.61 ton/boat/month) is about 1.45 times that of the northern region of the Lake (i.e. 1.11 ton / boat / month). The variation of CPUE for five successive years (1988 - 1992) shows remarkable annual and monthly changes in the CPUE for fishing

grounds, where high catches are recorded. Generally, there is a decrease in the average CPUE in the northern as well as the southern fishing grounds. However, it seems that the southern fishing grounds are still higher in the density of fish than the northern fishing grounds.

The average CPUE during 1966 -1996 showed that it was less than one ton/boat/month during 1966 -1977, then fluctuated between about one to two ton/boat/month during 1978 - 1992. Maximum CPUE was attained in 1981 (1.90 ton / boat / month), followed by a decline to an average of 0.88 ton / boat/ month during 1993 -1997, and reached 0.64 ton/boat/month in 1999. It is worth mentioining that during the last 10 years, a part of the commercial catch was sold in the black market illegally with high prices. This leads to a drop in the figures of CPUE.

The CPUE-effort relationships of *O. niloticus* and *S. galilaeus* are presented. The general trends of the relationships with respect to the total catch and tilapiine catch were directed towards increase with time throughout 1966-1992. However, excluding the increased CPUE data of the initial years of Lake formation (1966-1972), CPUE decreased with the increased effort. The CPUE-effort relationships of *Hydrocynus, Lates, Labeo, Bagrus* and *Clarias* spp. showed decreased trends in spite of the variable fluctuation throughout 1966-1992. These trends were due to the continuous decline in their catch. Thus in recent years the caches of *Bagrus* and *Clarias* spp. were insignificant hence not recorded in the actual annual Lake prodcuction.

The yearly recruits (R) of *O. niloticus* and *S. galilaeus* using Virtual Population Analysis (VPA) for 1966-1992 are presented and the trends of recruitment variations with time (Y) are described. The relationships between recruits of tilapiine species considered and water levels of the preceding year (WL1) are presented. The water level of the preceding year affects the recruits of *O. niloticus* and *S. galilaeus* by 49.88 and 57.78%, whereas the other factors control them by 50.12 and 42.22% respectively. Such water-level low effects were emphasized by the correspondence of high recruits with low values of water level. In some years, there was a decline in recruits in spite of high water level. Accordingly, the relatively high significant R-WL1 correlations of the two tilapiine species could not be reflected by their catch-WL1 relationship.

The pattern of variations in egg production/recruitment (E/R) and mature stock / recruitment (S/R) of *0. niloticus* and *S. galilaeus* of Lake Nasser in 1966-1992 period with two assumptions for age groups of the spawning stock shared are presented. Beverton & Holt's (1957) S/R model was fitted to stock-recruitment data of *O. niloticus* and *S. galilaeus* and the estimates of its parameters are given.

Lake Nasser has passed over three successive trophic states :

1- Mesohumic-mesotrophic with a fish production ranging from 15 to 30 kg/ha/yr during 1968-1971.

2- Mesotrophic-eutrophic (i.e. fish production 30-60 kg/ha/yr) during 1972-1977.

3- Eutrophic (i.e. > 60 kg/ha/yr) during 1978-1998.

Therefore, during 1968-1996, Lake Nasser has gradually changed over from the mesohumic-mesotrophic state to the highly eutrophic one, if compared with the other man-made lakes of Africa as Lake Kariba (30-57 kg/ha/yr) or Lake Volta (43.4 kg/ha/yr).

It is worth mentioning that in 1997, 1998 and 1999 there was a sharp drop in the estimated fish yield which reached 44.08, 40.11 and 28.28 kg/ha/yr respectively. This is mainly attributed to that, a large potrion of the catch is sold in the black market with high prices, and hence not recorded in the official catches. The low figures of estimated fish yield in 1997, 1998 and 1999 do not represent the actual yield.

On the basis of the Morphoedaphic Index (MEI), several estimations of potential annual yield of Lake Nasser fisheries have been made. The MEI-based models reflect only one of the aspects produced by the variable ecological, environmental and fishery factors. Their validity for application is limited by their continuous updating. Therefore, administrators and fishery managers usually seek other models to obtain more precise predictions and to make definitive plans for the future.

A regression model for predicting tilapia catch from the water level and length of shoreline of the Lake was introduced. The shoreline length at 3 years before (L_{t-3}) was selected as one of the explanatory variables.

Fish production from Lake Nasser was estimated also from the primary net production of phytoplankton.

The maximum sustainable yield (MSY) was estimated by using different methods :

The MSY for *O. niloticus, S. galilaeus* and L. *niloticus* during 1966-1992 were roughly estimated according to Cadima's estimator. However, these yearly variable MSY's values are overestimated since they are influenced only by yearly catch and total mortality and not by long-term data.

The yield per recruit (Y/R) with varying inputs of age at first capture (Tc) and fishing mortality (F) were calculated. Also, the biomass per recruit

(B/R) and relative Y/R models were used in estimating MSY/R and relative MSY/R´ for different values of Tc. The MSY/R of both *O. niloticus* and *S. galilaeus* increases with the increase of age at first capture (Tc). The recruits required to obtain MSY of F_{MSY} (30,000 ton) are 647,948,164 and 518,134,715 for Tc = 1 and 3 respectively. The environmental and biological conditions of the Lake should be controlled to multiply the current recruits of *O. niloticus*, at least by a factor of 9-11 for MSY at Tc = 1-3, those of *S. galilaeus* should be multiplied by at least a factor of 5-6 for MSY (17,000 ton) at Tc = 1-3.

S. galilaeus , which has a slow-growing nature and caught early in life, has a lot of potential weight to put on and this brings about a maximum yield at low fishing rates. Such low rates allow fish to escape the gear and therefore realize some of their growth potential. On the other hand, *O. niloticus* takes its way towards fast-growing and producing Y/R-curve of the plateau type even at lower rates of Tc.

Catch-effort data of khors in 1988-1994 were fitted to Schaefer's Model, and the MSY per month per fishing area were estimated. Subsequently, the total MSY of the Lake was found to be 59,742.24 ton. The total-catch-effort data of 1973-1992 were fitted to the hyperbolic model, and the calculated MSY was 55,616.69 ton. The holistic model of Schaefer (1954) was applied to the CPUE of 1973-1992 for tilapiines and of 1966-1992 for the other group of fishes. The total MSY was 61,644.78 ton, and tilapiines represented 90.74% of it. The MSY of other fish groups was low and reflected the severe conditions that control their production. Taking Lake area (A) in consideration, due to its effect as spawning grounds on the catch, a proposed modification of Schaefer's Model was fitted to 1981-and 1989-total catch-effort. The total MSY of the Lake with a maximum area of 1,250,000 feddan (505868 ha) was estimated to be 57,492.27 ton with f_{MSY} =1313 boat, and the tilapiine MSY was estimated to be 53,755.27 ton.

A Graham curve from the relation of surplus production to biomass was fitted to catch-effort data of *O. niloticus* and *S. galilaeus.* The MSY of the two tilapiine species (54,107.07 ton) was nearly similar to that determined by Schaefer's Model, while f_{MSY} was different. The total MSY was estimated to be 57,868.52 ton.

The surplus production/biomass and biomass relationship was used in calculating the maximum sustainable yield, which was 26,863.28 ton for *O. niloticus* and 27,243.79 ton for *S. galilaeus.*

The Generalized Stock Production Model of Fox (1975) was fitted to catch-effort data of *O. niloticus* and *S. galilaeus* of Lake Nasser for 1966-1992. The MSY was estimated to be 25,336.9, 15,614.1 and 15,347.5 ton for *O. niloticus* and

32,970.0; 16,542.7 and 13,657.7 ton for *S. galilaeus* according to the Asymptotic, Gompertz and Logistic Models respectively. Except for those estimated by the Asymptotic Model, the other MSY's in comparison with the above estimated ones showed considerable variations and were underestimated. The total MSY of Lake Nasser was estimated to be 62,360.32 ton according to the Asymptotic Model, considering the average percentage of tilapiine species (93.5%) of 1991-1992.

The yield, value of yield and biomass of *O. niloticus* and *S. galilaeus* were calculated using the age-based Thompson & Bell Model. The MSY's of *0. niloticus* and *S. galilaeus* were 30,127.64 and 17,692.34 ton respectively. When the price per kilogram is 2 LE (the fixed price by the authorities), the actual price in the market is not less than 9 LE/kg), the maximum sustainable economic yield value (MSE) will be 60,254,380 LE and 35,384,670 LE for *O. niloticus* and *S. galilaeus* respectively.

The food quantities required to obtain the MSY were estimated. *O. niloticus* and *S. galilaeus* can be identified as bacterial, phytoplankton filter and plankton feeders; also these fishes can be considered predator fishes on rotifers, copepods and ostracods. In other words, these species feed at more than one trophic level. It is obvious that Lake Nasser ecosystem is in favour of those species exhibiting more flexibility in their diets, which may cross trophic level boundaries, viz., *O. niloticus* and *S. galilaeus.*

In recent years, the herbivorous *Tilapia zillii* spread in Lake Nasser. *T. zillii* plays a multiple role as a plant feeder by making nutrient material available for plankton or making its faecal masses available for other fishes. Further studies on the biology of *T. zillii* and its impact on Lake Nasser ecosystem should be carried out in the near future. Also, it is required to investigate the trophic level interactions and to determine food requirements for different fish species inhabiting Lake Nasser. Caddy's (1983) equation shows the feeding rate in relation to body size and temperature.

The total annual food (ton) required to obtain the mean maximum sustainable yield (i.e. 30,000 ton) of *O. niloticus* was estimated using Caddy's (1983) estimator.

Chapter 10
Fisheries Development

SOME NOTABLE FEATURES OF LAKE NASSER

Lake Nasser, which is an elongated water body, is among the largest man-made freshwater bodies in the world. Its various dimensions depend on the volume of its water (Table 1 & Fig. 1). The water volume in the Lake fluctuates greatly from year to year according to the annual net water input into the Lake. The highest water level (181.60 m) was attained in 1999, while the lowest one (150.62m) was recorded in 1988. The annual Lake level fluctuations are in the order of 5-10 m. The fluctuations of the Lake's water level is one of the most important factors affecting its ecology. The Tushka spillway was designed as a device to allow the discharge of excess flood water, it was used for the first time, since the construction of High Dam, in October, 1996.

One of the most outstanding features of Lake Nasser is the elaborate complex of numerous (85) major khors (dry desert wadies), the longest of which is Khor Allaqi, which has a length between 40 and 80 km. The khors are biologically the richest areas of the Lake. Their shallow waters provide better breeding grounds for fish and the gentle slopes of the inner khors, compared with the rocky and steep shores of most of the Lake, allow deep alluvial deposits to accumulate, providing a great chance for vegetation to grow. Dominant macrophytes in the shallow margins of the Lake are *Najas armata* and *Najas horrida*. Birds are the second most prominent faunal element after fish.

The Lake is a fairly hard-water, eutrophic lake, nitrate and dissolved phosphate concentrations in the water are moderate to high. Variations in water turbidity are partly due to variation in suspended sediment loadings, related to the seasonal flows of silt-laden flood water into the Lake, which takes place between August and October every year. At this time, transparency is reduced to 20-25 cm; outside the flood season transparency increases to 50-350 cm. A further factor leading to the increase

in turbidity is phytoplankton blooms in the oxygen saturated surface layers of the Lake. Transparency in the khors is less than that in the open Lake water, due to the abundance of inorganic suspended material.

Lake Nasser is one of the most important national sources of fish production, contributing from 10 to 15% of the total inland fisheries production in Egypt, or about 10% of Egypt's total country production.

One of the gratifying aspects of the creation of man-made lakes is fishery development. The rapid increase in nutrient level following filling of a lake is paralleled by increase of fish production (after a time lag) resulting in higher yields (Henderson 1973). Jackson (1966) reviewed the establishment of fisheries in tropical man-made lakes. The morphoedaphic index (MEI), which was originally described as a first-approximation method for yield assessment in north-temperate lakes (Ryder 1965), has been successfully applied to African inland waters (Regier & Henderson 1971, Henderson 1973, Ryder *et al.,* 1974, Bishai & Khalil 1987). The mean depth of the reservoir or lake and the mean value of total dissolved solids or any of its correlates such as conductivity or total alkalinity are used for the computation of the morphoedaphic index. Applying MEI for Lake Nasser, the potential yield was estimated as 19,000 ton at 180 m level or 32 kg/ha , which is considered as moderate compared with other African lakes (Ryder & Henderson 1974). Based on catch statistics for Lake Nasser, the estimated fish yield ranged from 18.01 to 27.52 kg/ha/yr during 1968-1971, and from 31.98 to 52.45 kg/ha/yr during 1972-1977, and from 63.36 to 116.99 kg/ha/yr during 1978-1996 (Table 141). The estimated fish yield, during the last period (1978-1996), is considered high compared with other African lakes.

FISH YIELD PREDICTIONS

The physical and chemical properties of Lake Nasser (Table 165), the positive and negative effects together with the unknown major factors affecting the productivity of the Lake (Table 166) were investigated by Ryder (1973). All these factors throw light on the problems of fisheries and help to get four potential yield predictions as follows:

Morphoedaphic Index (MEI) Method

This index was applied in north temperate lakes (Ryder 1965), then in African inland waters (Regier *et al.* 1971, Henderson 1973). It is based upon data on conductivity, where they are converted to TDS (total dissolved solids) from the values of Hutchinson (1957). When applying this method to Lake Nasser the potential yield was estimated as 10,000 m.t. at 160 m level and 19,000 m.t. at the level 180 m.

Table 165 **Some physical and chemical features of Lake Nasser (Ryder 1973).**

Parameter	Maximum	Minimum	Mean
Surface temperature (°C)	32	17	25
O_2 absolute (mg/1)	7.8	0	–
O_2 saturation (%)	160	0	–
pH	9.4	6.8	8.4
Conductivity (µmhos/cm)	225*	200	210
Total dissolved solids (mg/1)	200	175	185
Alkalinity (mg/1)	2.30	1.87	2.01
Transparency (m)	3.5	0.15	1.5

* Conductivity values may attain 300 µmhos cm^{-1}

Rawson Model Method (1962)

This was extended to African lakes and reservoirs by Fryer & Iles (1972). It depends on the mean depth. According to this method the yield of Lake Nasser would amount to 10,000 mt. at 160 m level and 16,000 mt at 180 m level.

Yield and Biomass (Gulland 1970)

This method depends on Gulland's relationships on the basis of known biomass of latent fish stocks:

Y = 0.4 MB

where,

Y = the long term yield.

M = natural mortality rate.

B = ichthyomass of exploitable stocks prior to fishing.

This method gave the figure of 11,000 mt. as an annual yield of fish.

Mediterranean fishery

Ryder (1973) found a close relation between Eastern Mediterranean catch and Lake Nasser catch (r = 0.952), but with 4 years earlier for the Eastern Mediterranean. Applying this method to Lake Nasser an annual yield of 8,000-13,000 ton was estimated.

THE YIELD PATTERN AT LAKE NASSER

In his mathematical model for estimating the yield pattern at Lake Nasser, Bazigos (1972) found that there is a close correlation between the

three variables

Table 166 **Some notable features of Lake Nasser (Ryder 1973).**

Positive effect	Negative effect	Major effect unknown
	Abiotic	
High shore development	Low transparency during flood due to inorganic turbidity. High mean depth of river channel.	Effect of sand storms.
Low mean depth of khors.	High surface temperature during summer.	High rate of evaporation
Moderate to long growing season.	Low water temperature during winter.	
Increase of nutrients during floods.	Low dissolved O_2 in hypolimnion during summer.	
	Biotic	
High incidence of phyto-plankton blooms Aquatic macrophytes and periphyton increasing markedly.	Phytoplankton mainly blue-green algae. Relatively low fish species diversity for a tropical lake may be indicative of low stability and a lack of resilience following stresses.	Community interrelation-ships
Well established zooplank-ton and benthos.	Low abundance and diversity of terrestrial vegetation.	
High mean size of fish and relatively high species di-versity suggesting insignif-icant effect of fishery in the southern part.	*Oreochromis niloticus* nests exposed by drawn- down.	
	Effects of fishery expressed in density dependent factors. Low diversity of benthic and planktonic animals. Low diversity of aquatic macrophytes and animals.	

which are total commercial landings, number of fishing boats and total surface area (annually).

The estimating equation is:

$$t^{X1} = a_{1.23} + b_{12.3}\, t^{X2} + b_{13.2}\, t^{X3}$$

where x_1, x_2, x_3 express the variables respectively.

The surface area was found to be responsible for the annual changes in total landings 1.33 times more than the variable of "number of fishing boats". More reliable estimates of the expected value of fishing activity are needed to get more reliable estimates for those potential yields predicted.

FISHING INDUSTRY

In Lake Nasser, there were about 12,000 fishermen in 1990 and 1991. Their number declined to about 9,400 in 1992. Five associations control the different sections of the Lake. Each of them serves fishermen from one of three governorates : Aswan, Qena and Sohag. Many of the fishermen are unqualified and might use unsuitable, illegal or degrading fishing techniques, to compensate for their inexperience. The littoral or best fishing grounds are usually fished more intensively than other areas. Some other areas are almost never fished (either because they are poor in fish, or because they are far from access to transportation). The fishing areas are allocated by Aswan Governorate. All the catch from Lake Nasser has to be delivered to the Egyptian Fish Marketing Company (for distribution throughout the country), or to Misr Aswan Fish Company, which processes some fish for local consumption. Some fish species (mainly tilapiine species) are taken by a small Fillet Factory in Aswan. The fish are sold to these companies at fixed prices.

The fishermen practice their activity in small (usually mechanised) boats, and they live in temporary huts constructed along the shores of the Lake. They are usually based close to areas with road access or freezing facilities to ensure rapid transport of their fish, particularly during summer.

FISHING REGULATIONS

1. It was suggested to enforce a closed fishing season in the whole Lake area yearly from March 15th to May 15th to prevent catching mature fishes, especially *Tilapia* spp. during spawning. This regulation started in 1990. Table 167 shows the variation of CPUE before and after applying prohibiting fishing in 1990. Adam & Mohamed (1995) considered the difference of the two means (2.3 ton / boat / month) as an effect of prohibiting fishing in 1990, especially that the water level during these years (before and after prohibiting fishing) was nearly the same (about 167 m). This regulation, however, was not applied during certain years due to political reasons.

Table 167 **Variation of CPUE before and after the enforcement of prohibiting fishing in Lake Nasser (Adam & Mohamed 1995).**

Year	CPUE (ton / boat / month)
Before prohibiting fishing	
1989	13.32
1990	11.43
Total	24.75
Mean	**12.40**
After prohibiting fishing	
1991	**16.00**
1992	**13.37**
Total	29.37
Mean	14.70
Difference between the two means	14.70 - 12.40 = 2.3 ton / boat / month (=18.5 %)

2. Regulations on fishing gears by prohibiting the use of bottom gill nets and trammel nets with small mesh size (< 12.5 cm) in order to prevent fishing tilapia at lengths less than 25 cm or body weight less than 500 gm.

FISHERIES POTENTIALS

As previously mentioned, the maximum fish landings was 34,206 ton from Lake Nasser in 1981. However, the potential of Lake Nasser fisheries appears to be higher, as it is one of the most productive large bodies of water in Africa. Primary productivity as well as the standing crop of plankton are known to be very high (2-3.5 $g/C/m^2/day$). Also, Lake Nasser is 4-5 times richer in total dissolved solids and 3-4 times richer in total alkalinity, when compared with other large African reservoirs studied (Entz *et al.* 1971), and it is obvious that the shoreline of Lake Nasser is 2-5 times longer in relation to its surface area. All these conditions indicate a large potential for fish production in the lake. The fertility of Lake Nasser is greater than that of Volta Lake, where the catch is estimated to be 60,000 ton per annum. Therefore, in spite of the comparatively small size of Lake Nasser (i.e. when the Lake is full, it amounts

to approximately two thirds of Volta Lake), the maximum sustainable catch may be of the same magnitude in both lakes. It should be taken into consideration that the area of Lake Nasser fluctuates due to annual changes in water level. Also, the available living space will be changeable. On the whole, assessment of the stocks of Lake Nasser could be safely undertaken for concrete estimation of the potential of its fisheries.

It is worth mentioning that the khors of Lake Nasser are more productive than the main channel. Thus, the mean value of chlorophyll *a* concentration is about 10.8 mg/m^3 inside Khor El-Ramla, while it is only 7.8 mg/m^3 outside the khor (Habib 1992 b). Consequently, fish production is higher in khors and littoral areas than in the main channel. As a matter of fact, the main channel, i.e. the deep areas, are not well exploited.

About 90% of the total fish production is *Sarotherodon galilaeus* and *Oreochromis niloticus* caught in the coastal area of the Lake. The offshore area of the Lake is not well utilized for fisheries except some catch of *Hydrocynus* spp., *Alestes* spp. and others.

Recently, much attention has been focused on the insufficiently utilized offshore region in order to increase fish production from the Lake by introducing a new commercial fish suitable to the Lake environment. The introduction of silver carp was suggested for open water areas of the Lake. However, it is advisable not to introduce any new fish species into the Lake, otherwise any impact due to its stocking will be difficult if not impossible to remedy.

RECOMMENDATIONS

Needless to say that the future economics of Lake Nasser fisheries look bright. But, in fact, various problems confront the Lake fisheries development. The factors affecting the decline of fish production may be summerized as follows:

1. The decline in Lake water volume changes the ecology of a large portion of the Lake. Thus, the spawning and nursery areas decrease sharply and this causes certain fish species to decline or disappear from the Lake. Also, the fishing grounds decrease and consequently there is a decline in fish production.

2. The coastal fishing grounds (the best fishing areas), which represent 20% of the total Lake area, are usually fished more intensively than the open water fishing areas (about 80% of the total Lake area). Some areas are almost never fished, because they are far from access to transportation.

3. Although the open water areas are rich in phyto- and zooplankton, there appear a few species that are able to feed on plankton in the Lake.

4. The competition between various fishing associations might lead to intensification of fishing efforts, and vice versa.

5. The number of fishermen declined from 12,000 (at the peak productive period of Lake Nasser) to 9,400 in 1992.

6. Many fishermen are unqualified and might use unsuitable fishing gears. They practice their activity in small mechanized boats and live in temporary huts.

7. There are problems due to the nature of the Lake, being relatively very long and narrow in the middle. Transportation of fish is a major problem. Fishermen have no facilities along the Lake to store the catch, but have to wait to use the facilities of the few carrier boats available. Considerable fishing time is lost just waiting for supplies to keep fishermen going. Transportation problem has two major aspects:

a. Transportation of catch to High Dam Harbour.

b. Transportation from Aswan to inland markets especially Cairo.

To improve fisheries of Lake Nasser, some suggestions are recommended:

I- For the best use of the Lake, comprehensive and continuous applied research should be considered in the following aspects :

a. ***Environmental and fish stock assessment studies***. It is well known that remarkable changes both in the environment and fishery have been occurring in Lake Nasser since the construction of the High Dam. Due to yearly fluctuations in the water level of the Lake, physical, chemical and biological changes should be followed continuously so that a clear picture of Lake conditions will be known. Continuous monitoring of the physical, chemical and biological factors affecting fish population dynamics are needed.

The knowledge of changes in surface area and volume of water at different water levels is very important for fish stock assessment and fishery development. For instance, the increase in the surface area of the khors, which represents the suitable breeding and nursery grounds for tilapiine species, the most important fish species, leads to an increase in total fish production, and vice versa . Changes in length of the shoreline and its slope are important factors for the development of periphytes and littoral fauna, the main food for tilapiine species, which form the major part of fish production (more than 90%).

It is required to investigate the trophic level interactions, and to determine food requirements for different fish species inhabiting Lake Nasser. Further studies on the biology of *Tilapia zillii* and its impacts on Lake Nasser ecosystem should be carried out in the near future. Thus, details of ecological and biological constraints are needed for the effective management and monitoring.

Adequate scientific knowledge on the present fish stocks, under the changing environmental conditions, should be taken into consideration. Assessment of the level of exploitation of the fishery relative to its potential is urgently needed for correct estimation of the maximum sustainable yield.

There is need to collect information on: the number and location of fishermen camps, the number of fishing boats and fishermen in camps, average days of operation per fishing boat during the year, average daily frequency of the haul per boat, length and mesh size by type of fishing nets used, size of the collected fish species in different months and according to various fishing grounds, the size and distribution of the hauled fish by species, release of tagged fish, and survey by echo-sounder. The accumulation of the aforementioned data will greatly contribute to detect early signs of overfishing and thereby enable a quick adaptation of corrective measures.

b. *Aquaculture studies.* These include both coastal and open water areas.

Coastal fishing areas : *Tilapia* species do not migrate far from their normal habitat. Hence, the fingerlings of *Oreochromis niloticus* released into the khors grow up to marketable size after few years. This is one of the effective methods to increase fish stocks.

Open water fishing areas: These areas are rich in both phyto- and zooplankton (Fishery Management Center, 1992). Since, there appears to be a few fish species that are able to feed on plankton, silver carp *(Hypophthalmychthus molitrix)* culture in net cages had been practiced in open water areas of Lake Nasser to fullfil the following:

a) The utilization of the open water area.

b) To utilize phytoplankton and also avoid the pollution which may happen owing to the decay of a large amount of these organisms.

c) To ensure other additional income for fishermen.

II- The total catch in the southern fishing grounds is 1.4 times as much as that in the northern fishing grounds, and also the value of CPUE in the southern fishing grounds is 1.7 times as much as that in the northern fishing grounds. Hence, it is suggested that higher number of fishing boats could be used in the southern part of the lake.

Ill- The hot climate of the Lake particularly during summer time, the presence of many fishing grounds far from Aswan, and that Aswan is far from the main consuming centre (Cairo), all these factors are in favour of encouraging fish processing in Lake Nasser. So, in addition to the two small factories (Fillet and Fish Meal) at Aswan, larger factories could be constructed at Aswan, where appropriate methods of fish processing have to be developed so that more products acceptable by the consumer can be developed. Tilapias *(Oreochromis niloticus* and *Sarotherodon galilaeus)* which are the most common

species in the Lake can give a good sundried product and the climate is suitable for this process. Kalb *(Hydrocynus* spp.) and raya *(Alestes* spp.) give a good smoke-canned product and as these fishes are common in the Lake, such a method of processing can be initiated.

IV- A fair percentage of fish caught from the Lake is salted in a very simple and primitive way. The main salted fishes are raya *(Alestes* spp.), kalb *{Hydrocynus* spp.), lebeis *(Labeo* sp.) and shilba *(Eutropius* and *Schilbe* spp.). Appropriate methods of salting of the aforementioned fish species may be developed to obtain good products of high quality and acceptable by the consumer.

V- Fishermen

a. To establish a policy on improving the conditions of fishermen to attract them to Lake Nasser. A project for settlement of fishermen at both the eastern and western sides of Lake Nasser, where the required services are already available, ought to be initiated.

b. To operate training courses for fishermen by staff members, in order to supply them with the necessary information to improve fishing and to be aware of the risks of using illegal gear which lead to destruction of the Lake fishery.

c. To improve transportation and preservation methods of fresh fish particularly from fishing grounds to High Dam Harbour.

CONCLUSIONS

The water volume in the Lake fluctuates greatly from year to year according to the annual net water input into the Lake. The highest water level (181.60 m) was attained in 1999, while the lowest one (150.62 m) was attained in 1988. The fluctuation of the Lake's water level is one of the most important factors affecting its ecology. The Tushka spillway was designed as a device to allow the discharge of excess flood water, which was used for the first time since the construction of High Dam, in October, 1996.

The physical and chemical properties of Lake Nasser, the positive and negative effects affecting the productivity of the Lake are discussed. All these factors throw light on the problems of fisheries and help to get four potential predictions as follows:

a- Morphoedaphic Index Method.

b- Rawson Model Method (1962).

c- Yield and Biomass (Gulland, 1970).

d- Mediterranean Fishery.

Applying the four mentioned methods, the annual yield prediction from Lake Nasser was found to range between 8 to 19 thousand tons. However, recent studies showed that the potentials of Lake Nasser fisheries appear to be higher and the maximum sustainable yield of tilapiine species, estimated by

various methods ranged between 29,005 and 58,970 ton (p. 410). It seems that the possible maximum sustainable yield of *Oreochromis niloticus* and *Sarotherodon galilaeus* (representing about 93% of the total fish catch) is around 55,000 ton.

Based on catch statistics for Lake Nasser, the estimated fish yield ranged from 18.01 to 27.52 kg/ha/yr during 1968-1971, and from 31.98 to 52.45 kg/ha/yr during 1972 - 1977; and from 63.36 to 116.99 kg/ha/yr during 1978 - 1996. The estimated fish yield during the last period (1978-1996) is considered high compared with other African lakes.

In the mathematical model for estimating the yield pattern at Lake Nasser, there is a close correlation between the three variables, which are total commercial landings, number of fishing boats, and total surface area (annually). The surface area is found to be responsible for the annual changes in total landings 1.33 times more than the variable of "number of fishing boats".

The khors (85 major) of Lake Nasser provide the most important habitat for fish to breed and feed, because of their shallowness and abundance of phytoplankton. The open and deep waters of the Lake are poor in fishes in spite of the fact that they are rich (to a certain extent) in plankton.

Five associations control the different sections of the Lake. The number of fishermen declined from 12000 in 1990 and 1991 to 9400 in 1992, and most of them are unqualified and might use illegal or degrading fishing techniques. The bottom gill nets and trammel nets with small mesh size (< 12.5 cm) must be prohibited. The best fishing grounds are usually fished more intensively, while other areas are almost never fished. All the catch has to be delivered to the Egyptian Fish Marketing Company. Some fish species (mainly *Tilapia* species) are taken by a small Fillet Factory in Aswan.

Regulation of a closed fishing season from March 15th to May 15th started since 1990. The difference between the two means of CPUE for 1989 / 1990 and 1991 / 1992, which was 2.3 tons / boat / month (18.5 %) may be considered as an indication of effectiveness of prohibiting fishing during 1990.

The maximum fish landings was 34,206 ton from Lake Nasser in 1981. However, the potential of Lake Nasser fisheries appears to be higher, as it is one of the most productive large bodies of water in Africa. Suggestions are recommended for fisheries development.

Chapter 11
Aquaculture Development

As previously mentioned, Lake Nasser is very rich in natural food of fish. Habib & Aruga (1987) estimated the average primary net productivity of phytoplankton in the whole Lake as 4.01 kg (dw) / m^2 / year, and accordingly the annual net primary production as 10.3 x 10^6 and 21.0 x 10^6 ton (dw) / year at water levels 160 and 180 m respectively. The latter authors pointed out that tilapia catch should be 22.7 x 10^3 and 46.2 x 10^3 ton / year at water levels 160 and 180 m respectively. However, the total fish production from Lake Nasser was only 20,601 ton in 1997 at a mean water level of 177.38 m. Therefore, it is necessary to conduct applied research in the field of aquaculture to maintain and increase the natural fishery resources of the Lake.

In Lake Nasser, there are three important problems to be solved, viz.,

1- Utilization of coastal areas, through mass production of Nile tilapia fry and their release to the khors.

2- Utilization of the open water area, through introduction of new pelagic fish species.

3- Restocking of indigenous fish species.

UTILIZATION OF THE COASTAL AREA

The coastal area of Lake Nasser is highly eutrophic, and very rich in both phyto-and zooplankton. It is almost suitable for *Tilapia* spp. *(Oreochromis niloticus* and *Sarotherodon galilaeus)* as feeding, breeding and also fishing grounds. Its area is great and reaches about 0.25 million acre, and it represents about 20% of the total surface area of the Lake. The coastal area produces about 95% of the total fish catch. Therefore, mass production of tilapia fry and their release to the coastal areas of the khors is of utmost importance in order to increase their fishery resources.

It was reported by FMC (Fishery Mangement Center) that the percentage of *0. niloticus* decreased to 41.8%, while that of *S. galilaeus* increased to 51.9%. The proportion of landed *0. niloticus* in the total catch of tilapia showed seasonal

variation, with a maximum level (60-70%) during February to April, and a minimum (10-20%) during June to September, in each year. This tendency suggested an indication of danger to *0. niloticus* resource in the Lake in the future. It should be mentioned that *0. niloticus* grows about twice in weight as *S. galilaeus* when 4 years old (page 251). Therefore, it was inevitable to carry out some trials on mass production of *0. niloticus* fry and their release in khors.

Mass Production of *Oreochromis niloticus* Fry

The Fishery Management Center (FMC) at Aswan worked on mass production of fry of Nile tilapia to stock Lake Nasser, as one of the economical methods for fisheries development. Most of the biological studies on *0. niloticus* were covered and the technique of mass production of fingerlings was applied to the hatchery constructed for that purpose.

Nomura (1983) worked out a plan to produce one million fry of *Oreochromis niloticus.* A summary of the plan is presented.

1. **Number of brood fish**

Brood fish, about 30 cm in body length and 1 kg in body weight, produces about 1000 eggs during a spawning season (Fig. 231). Survival rate from eggs to fry (5 g in body weight) is 50%. Hence, the number of eggs required is two million. The number of female brood fish required to produce one million is 2000 (2,000,000 ÷ 1000). As the recommendable sex ratio at spawning time is 1:1, hence 2000 male brood fish are also required. Thus the total number of brood fish needed is 4000.

2. Kinds, area and number of ponds

a- Brood fish-spawning ponds. Total area 4,000 m^2 – size/pond= 8 x 12.5 x 1.5 m (1 m water depth), number = 40 ponds

Where : total weight of brood fish = 4000 kg (an average weight 1 kg, total number of fish = 4000), carrying capacity of brood fish 1 kg/m^2.

b- Nursery ponds

Area (m^2)	Number	Total area	Height of wall	Water depth (m)
10 x 15m = 150	15	2,250 m^2	1.3m	(0.8)
5 x 10 = 50	40	2000	1.3	(0.8)
3 x 5 = 15	30	450	1.0	(0.6)
2 x 4 = 8	25	200	1.0	(0.6)
1 x 4 = 4	25	100	1.0	(0.6)
Total	135	5,000		

Where : total weight of fry produced = 5000 kg (an average weight 5 g, 1 million in number), carrying capacity of fry = 1 kg/m^2.

Total area of ponds (a + b) = 9000m^2 = (0.9 ha).

3. **Water supply system**

Elevated tanks. Two tanks with a water capacity of 40 m^3 (4 x 2.5 x 4m). Water is supplied to each elevated tank by pumping up at a rate of 20 l/sec from the middle layer of the Lake, and the water in the tanks is supplied to each pond through pipes by gravitation. Pumping activity is regulated by the automatic on-off switch set on the elevated tanks.

4. **Fish feeds preparation house**

Total weight of brood fish is 4000 kg. As the feeding rate for brood fish is 1.5% of total body weight at 25°C water temperature, the daily amount of feeds required = 60 kg (4000 x 0.015) or 22 ton per year. On the other hand, total weight of fry produced is 5000 kg (1,000,000 X 5 g). By using a conversion factor 1.8, the total weight of feeds required to produce 1 million fry (from alevin to 5 g fry) is 9,000 kg (5000 x 1.8). It takes 40 days to grow up to 5 g from alevin, so daily amount of feeds is 225 kg (9000 ÷ 40). From the above calculations, the average amount of feeds to be prepared daily for both brood fish and fry is 285 kg (60 + 225), or 31 ton per year.

For the preparation of these large amounts of feeds, equipment for mixing, chopping, drying and sieving is necessary. Also, it is essential to set up cold storage for feed materials and fish feeds (30 ton capacity at – 5°C). The area of the house needed is about 65 m^2 (6.5 m x 10 m), including a cold storage area.

Shenouda (1997a) reported on the intensive production of Nile tilapia fry in the Fishery Management Center at Aswan (FMC). The report includes the followings:

a. Preparation of fishing equipment and collection of the brood fish (males and females) during January to April 1995.

b. Preparation of a wet lab and nursery equipment at the end of March 1995.

c. Intensive production of *0. niloticus* fry during 1995 was carried out from May to October 1995 at an average water temperature of 25.5 ± 3.0 °C with a maximum in September and a minimum in October. The relation between body weight and number of mature eggs / female for *0. niloticus* (Fig. 231) shows that the number increases with increase of body weight.

Feeding of Nile Tilapia Fry with Natural and Artificial Feeds

Sufficient and continuous supply of suitable and economical food for Nile tilapia fry is one of the most important items in a tilapia hatchery. On running an experiment, Shimura (1992b) observed that *0. niloticus* fry of total length 0.9-1.5 cm prefer *Moina* sp. Small fry being 0.9 cm long aggressively catch *Moina* sp., especially small ones (about 0.6 mm long). Large fry (i.e. 1.5 cm long) easily catch mature *Moina* sp. (i.e. 1.2 mm long). They feed on not only

zooplankton, suspended materials, but also bottom dwelling organisms: *Chironomus* larvae (Insecta, Diptera). Nile tilapia fry seem to be omnivorous and feed on many kinds of food items.

Artificial diet composed of scrap tilapia fish meal containing 48.1% crude protein was used as food for *0. niloticus* fry (Shenouda 1995a).

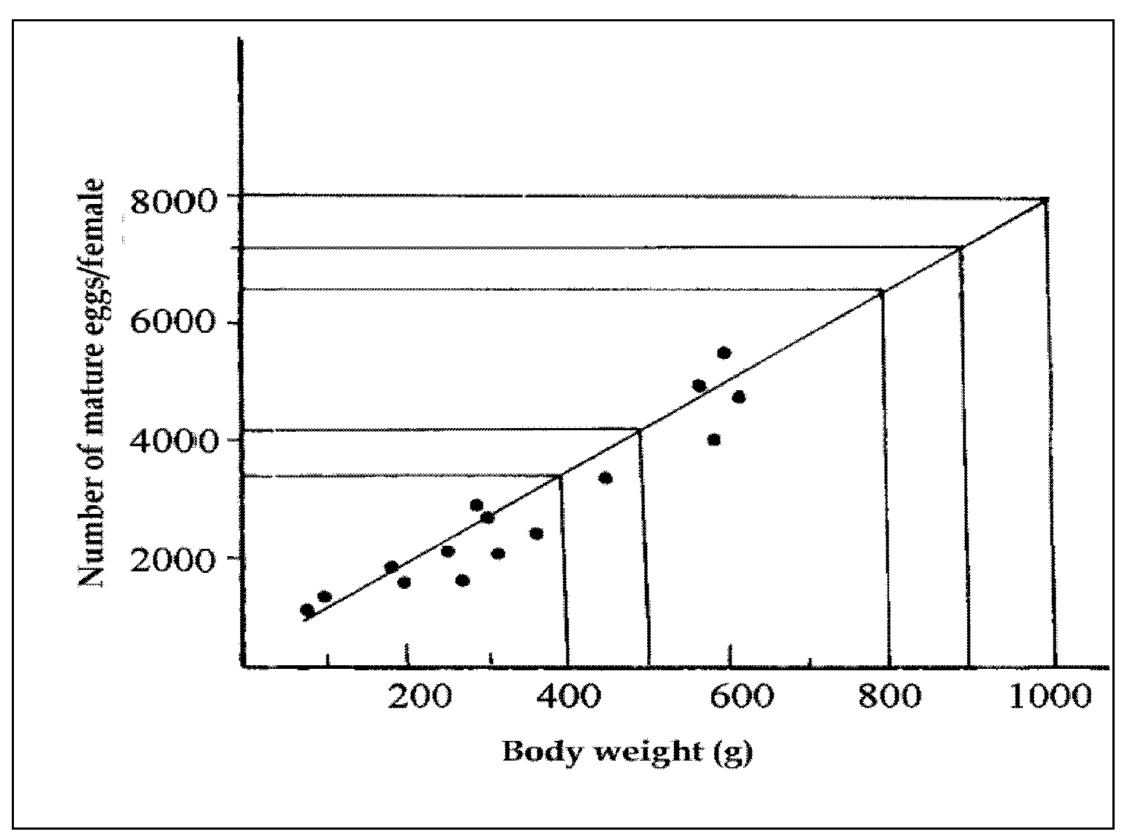


Fig. 231 **Relation between female body weight and number of mature eggs of *Oreochromis niloticus* (Shenouda 1997a).**

Effect of Dietary Protein Levels on Growth Performance, Feed Conversion Ratio and Protein Utilization in Fry of *0. niloticus*

Shenouda (1995a) used readily available scrap tilapia meal in formulating seven diets with different levels of protein (Table 168), which he used to feed Nile tilapia fry (average weight 1.89 ± 0.029g) stocked in eight glass aquaria (60 x 50 x 40 cm) with 100 l water. The latter author carried out the experiment for 30 days, and the fry were fed daily with 10% of their body weight. The feed was offered in equal amounts, as a paste, twice a day. The result of the experiment may be summarized as follows :

1. The growth of Nile tilapia fry (Fig. 232), survival rate and feed conversion ratio (FCR) (Table 169) indicate that the highest growth and best feed conversion ratio were obtained when using a diet containing 31.6% crude protein.

Table 168 **Composition of experimental diets of *Oreochromis niloticus* fry (Shenouda 1995a).**

Ingredients	Diet No. & %							
	1	2	3	4	5	6	7	Control
Fish meal	10	20	30	40	50	60	70	Unfed
Wheat flour	24	24	24	24	24	24	24	
Feed oil	1	1	1	1	1	1	1	
Vitamin mix.	1	1	1	1	1	1	1	
Mineral mix.	1	1	1	1	1	1	1	
Cellulose	63	53	43	33	23	13	3	
Crude protein (%)	7.5	12.4	17.2	22	26.8	31.6	36.4	
Crude fat (%)	2.7	4	5.3	6.5	7.8	9.1	10.3	

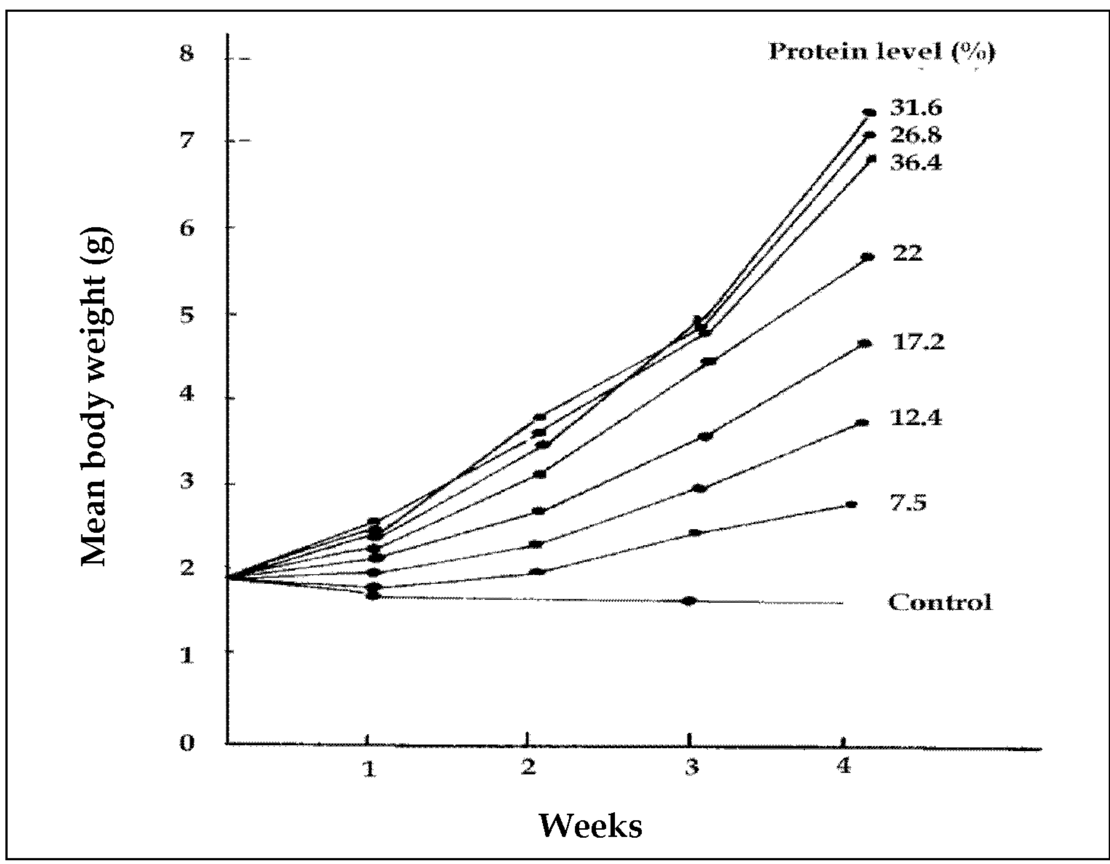


Fig. 232 **Growth of *O. niloticus* fry fed on diet of different protein levels** (Shenouda 1995a)

2. The gain in weight increased progressively with increasing the level of protein up to 31.6% (Table 169, and Figs. 233 and 234).

2. Protein efficiency ratio decreased with increasing levels of crude protein more than 25% (Table 170 and Fig. 237).

Table 169 **Stocking rate, survival rate, growth and food conversion ratio (FCR) of *O. niloticus* fry with different levels of dietary protein for 30 days (Shenouda 1995a).**

*Diet No.	Number and weight of fry						Weight increment					
	At the beginning			At the end								
	No. of fry	Total weight (g)	Mean weight (g)	No. of fry	Total weight (g)	Mean weight (g)	Total (g)	%	Mean weight (g)	Average daily growth (g/fry/ day)	Feed (g)	FCR
1	50	95	1.9	50	143	2.86	48	50.5	0.96	0.032	240.6	5
2	50	92	1.48	50	191	3.82	99	107.6	1.98	0.066	261.6	2.64
3	50	94	1.88	50	236	4.72	142	151	2.48	0.094	279.1	1.97
4	50	94	1.88	50	310	6.20	216	229.7	4.32	0.144	304.1	1.42
5	50	96	0.92	50	361	7.22	265	276	5.30	0.176	345.6	1.3
6	50	96	1.91	50	372	7.44	276	287.5	5.52	0.184	328.1	1.19
7	50	95	1.9	50	347	6.94	252	265.2	5.04	0.168	335.1	1.33
8 (control)	50	95	1.9	45	77	1.71	-18	-18.9	-0.19	-0.006	-	-

Food conversion ratio (FCR) = feed weight (g) /g live gain (g). * Refer to table 168 for diet composition.

Table 170 **Growth, protein efficiency ratio and food conversion ratio (FCR) of *0. niloticus* fry fed on different protein levels (Shenouda 1995a).**

Diet (% protein)	**Initial (wt. g)**	**Final (wt.g)**	**SGR***	**PER"""**	**FCR**
7.5	1.9	2.86	1.36	2.66	5
12.4	1.84	3.82	2.43	5.050	2.64
17.2	1.88	4.72	3.06	2.958	1.97
22	1.88	6.20	3.97	3.197	1.42
26.8	1.92	7.22	4.41	2.861	1.3
31.6	1.92	7.44	5.51	2.666	1.19
36.4	1.9	6.94	4.31	2.066	1.33

* SGR (specific growth rate) = 100 (final weight / initial weight / days).

** PER (protein efficiency ratio) = weight gain / days/protein intake.

4- Specific growth rate and average daily growth increased with increasing dietary protein level up to 31.6%, while it decreased with 36.4% protein level (Tables 169 and 170, and Figs. 235 and 236).

Shenouda (1995a) concluded that the best dietary protein level for fry of Nile tilapia *(0. niloticus)* was 31.6% at the feeding rate 10% of body weight per day, and the available scrap tilapia meal is a suitable protein source for Nile tilapia fry diets.

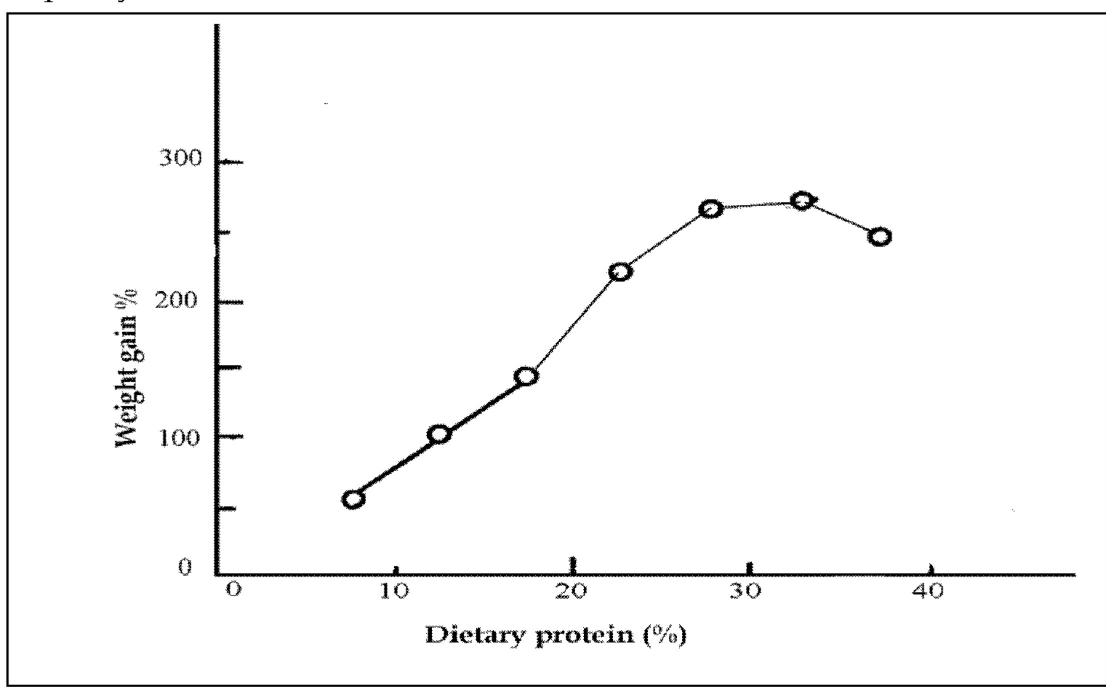


Fig. 233 **Relation between protein level of diet and body weight gain in *0. niloticus* fry (Shenouda 1995a).**

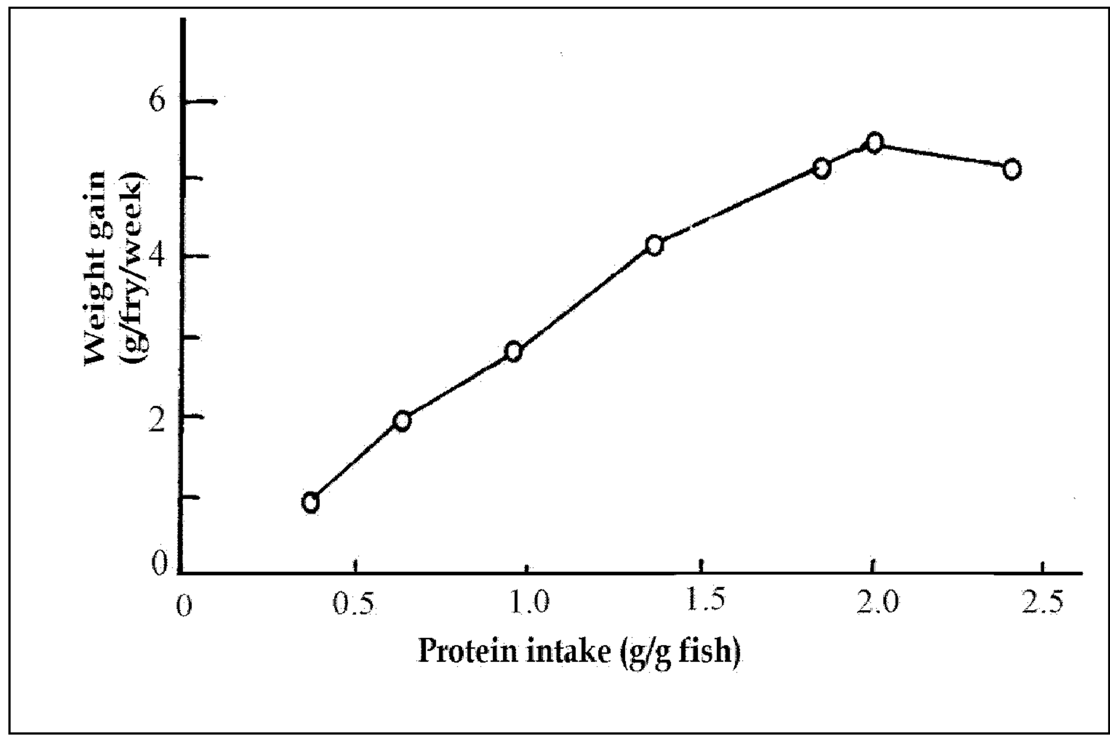


Fig. 234 **Relationship of dietary protein intake to weight gain in *0. niloticus* fry (Shenouda 1995a).**

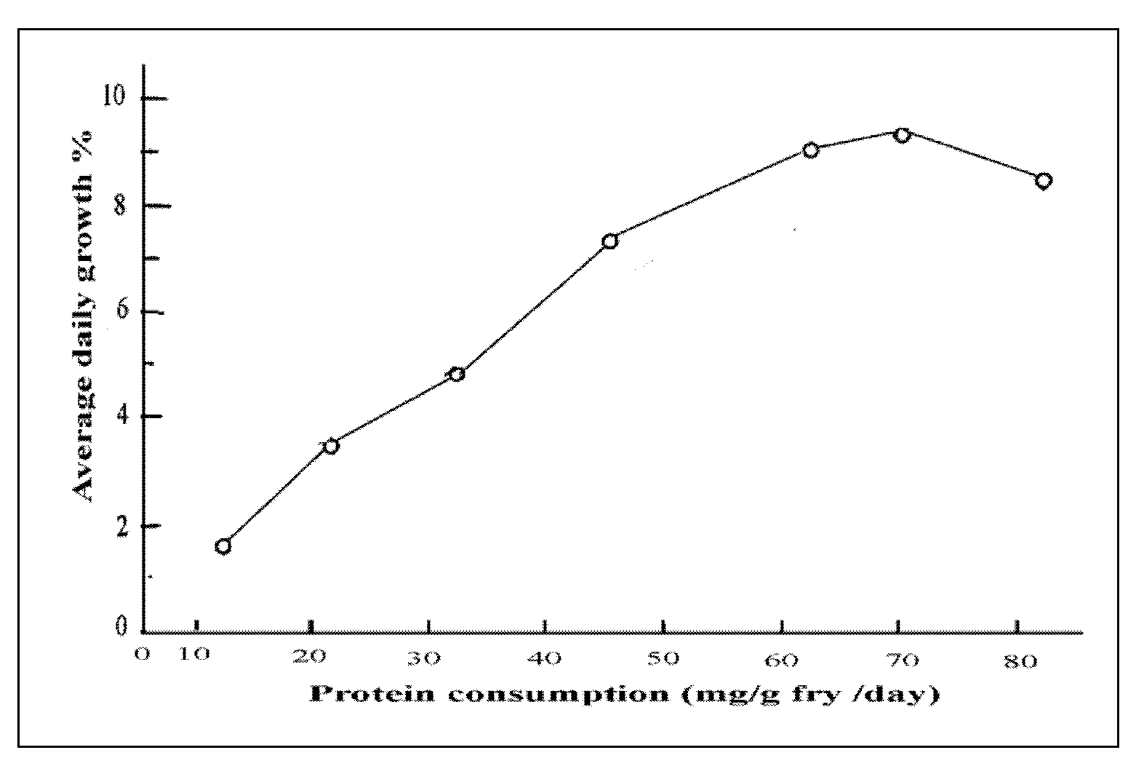


Fig. 235 **Relationship of average daily growth percent (ADG%) to protein consumption of *0. niloticus* fry (Shenouda 1995a).**

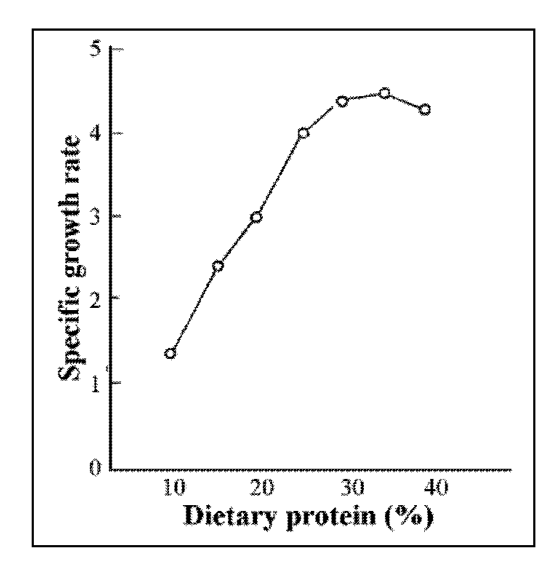


Fig. 236 **Effect of dietery protein levels on specific growth rate of *O. niloticus* (Shenouda 1995a).**

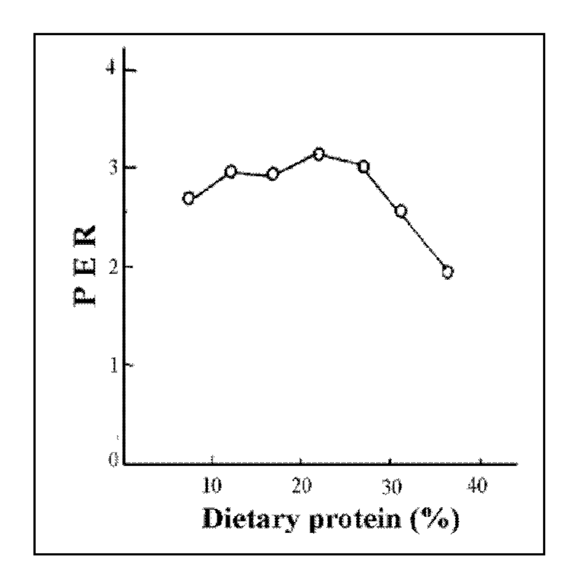


Fig. 237 **Effect of dietary protein levels on protein efficiency ratio (PER) of *O. niloticus* fry (Shenouda 1995a).**

Nile Tilapia Fry Release to Lake Nasser and Their Effect on Fish Production

The Fishery Management Center at Aswan (FMC) released fingerlings of *0. niloticus* in the southern area of Khor Kalabsha (Fig. 238) every year since 1988

till 1993. The number of released fry and the results are shown in Table 171 and Figs. 239-243. It is noticed that in the area where the fry are released, (southern area) a decrease of the percentage of fish yeild occurred only in 1989, which may be related to stopping of fishing from January to June (Agaypi, 1995a). The percentage increase of the catch compared with the catch of 1988 shows the effectiveness of fry releasing in the southern area of the Khor. The catch ratio in the southern area is higher than in the other areas. Moreover, the effectiveness of fry releasing is more evident in 1991 and 1992 than in 1993. The effect of fry releasing depends on minimum water level and the shape of the shoreline. The minimum water level was 150.62 m in 1988, while it was 164.3 m in 1989. When the water level increases in Khor Kalabsha (with a flat shoreline), the shallow water area expands and so the spawning grounds increase, and thus natural spawning increases. Detailed information on the number of operating fishing boats, composition of *0. niloticus* and *S. galilaeus,* interviews with fishermen, experimental fishing, tag experiment, etc. are necessary for a precise evaluation (Agaypi 1995a).

***Table 171* Effect of release of *0. niloticus* fry in the southern area on tilapia catch of Khor Kalabsha.**

	Year					
	1988	1989	1990	1991	1992	1993
Minimum water level (m)	150.62	164.30	163.72	162.23	163.84	167.24
No. of fry released	522,000	425,000	557,000	417,000	556,000	977,000
Mean body weight (g) of released fry	7.4	4.4	2.0	5.4	2.5	3.2
Total fish catch (ton)	663(100%)	652(100%)	949(100%)	2741(100%)	1963(100%)	1078(100%)
Catch from:	%	%	%	%	%	%
Entrance	209(31.5)	420(64.4)	269(28.3)	767(28)	297(15.1)	323(30)
North	293(44.2)	134(20.6)	228(24.1)	962(35.1)	919(46.8)	396(36.7)
South	161(24.3)	98(15.0)	452(47.6)	1012(36.9)	747(38.1)	359(33.3)
% increase and % decrease of catch compared with catch of 1988:						
Entrance (%)	--	+ 101	+ 29	+ 267	+ 42	+ 55
North (%)	--	- 54	- 22	+ 228 *	+ 214	+ 35
South (%)	--	- 39	+ 181	+ 529	+ 364	+ 123

Data are based on report by Agaypi (1995a).

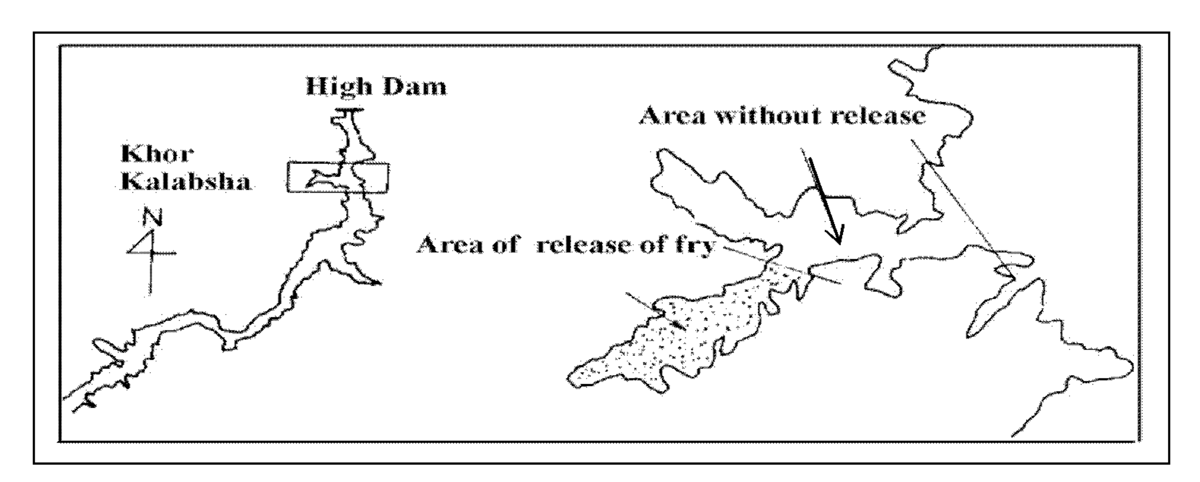


Fig. 238 **Location of Khor Kalabsha in Lake Nasser (Agaypi 1995a).**

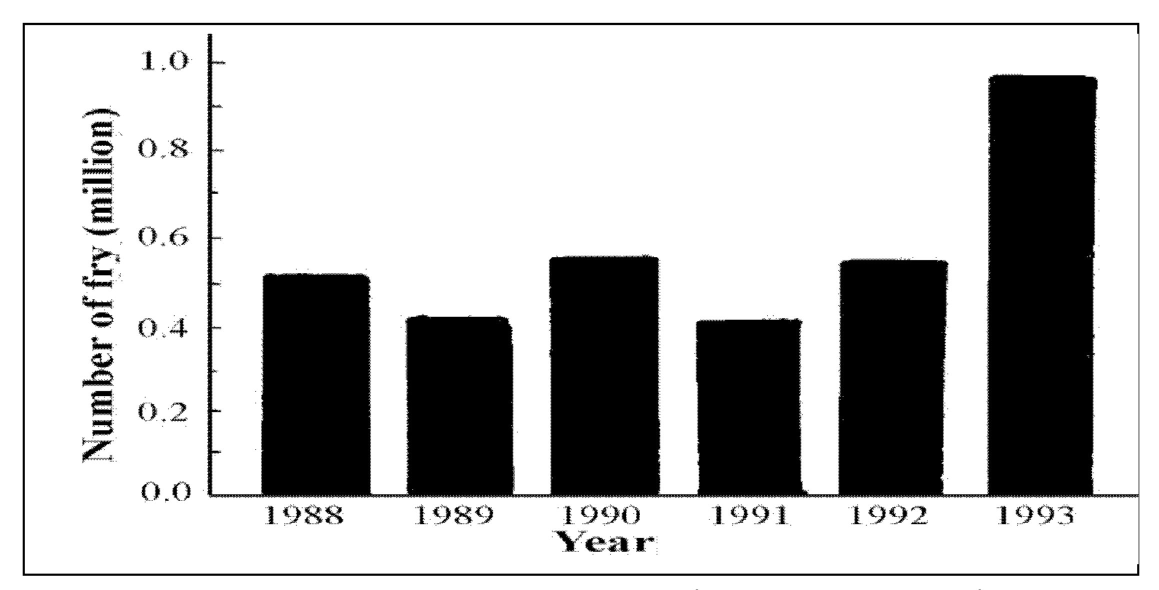


Fig. 239 **Number of *O. niloticus* fry released in the southern region of Khor Kalabsha (Agaypi 1995a).**

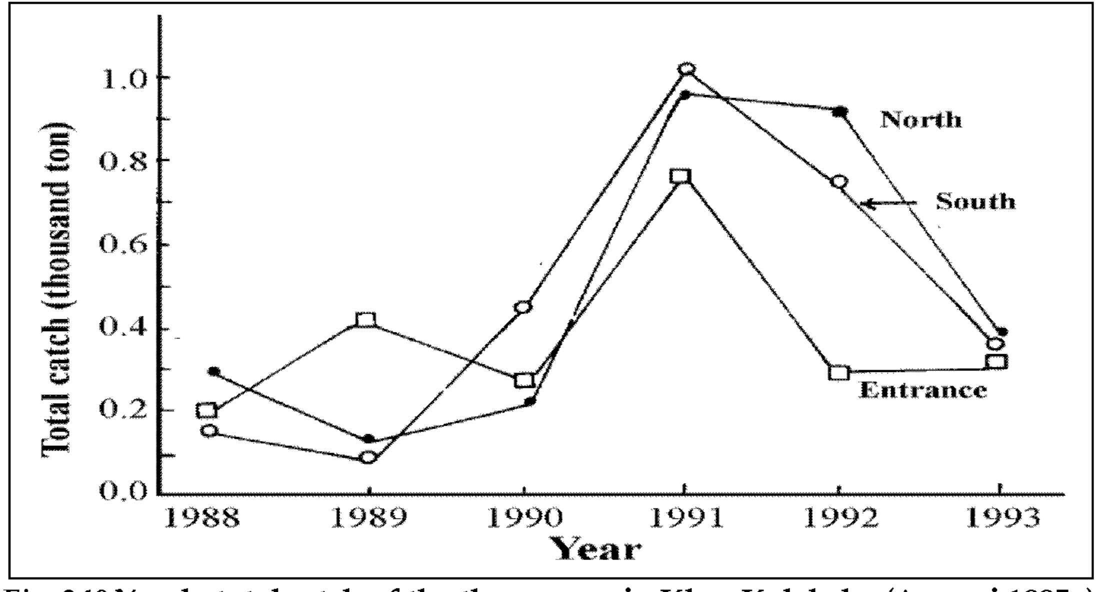


Fig. 240 **Yearly total catch of the three areas in Khor Kalabsha (Agaypi 1995a).**

Agaypi (1996a) pointed out that release of *0. niloticus* fry in Khor El Ramla started from 1991 to 1994 with increase of the released fry from 164,000 to 1,175,000 (Fig. 242). The results were manifested in 1994 by an increase of tilapia catch from 1197 ton in 1993 to 1870 ton in 1994 (Fig. 244). Thus assuming that fish are caught at an average age of 2 years, so the release of about one million tilapia fry in 1992 led to an increase of the total catch by 56%. It should be mentioned that during 1993 and 1994, the total Lake catch of *Oreochromis niloticus* was decreasing from about 14,884 ton to 9,111 ton from about 20% of the total Lake area. Thus, it can be concluded that fry stocking of khors and applying proper fishery management (prohibiting the use of illegal gear, care to the fry released, no overfishing, etc.) may increase fish production from Lake Nasser.

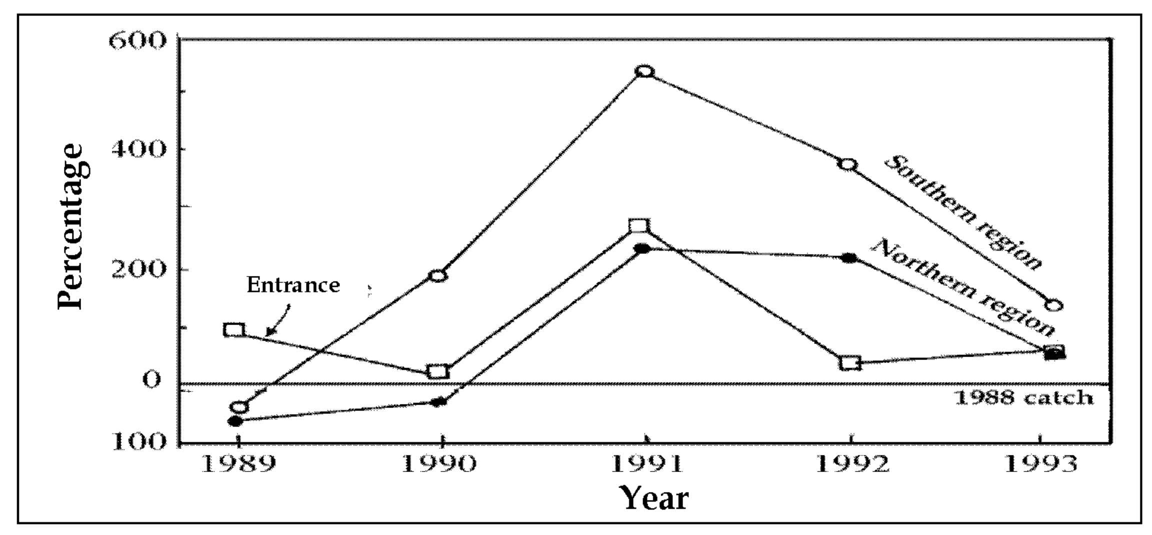


Fig. 241 **Percentage increment and decrease of catch in Khor Kalabsha compared with 1988 (Agaypi 1995 a).**

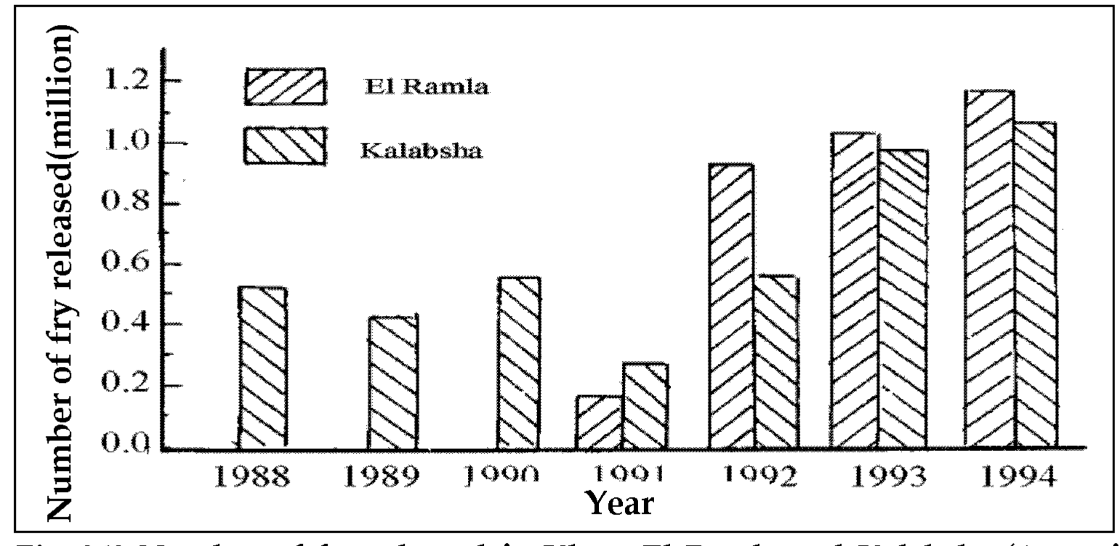


Fig. 242 **Number of fry released in Khors El Ramla and Kalabsha (Agaypi 1996a).**

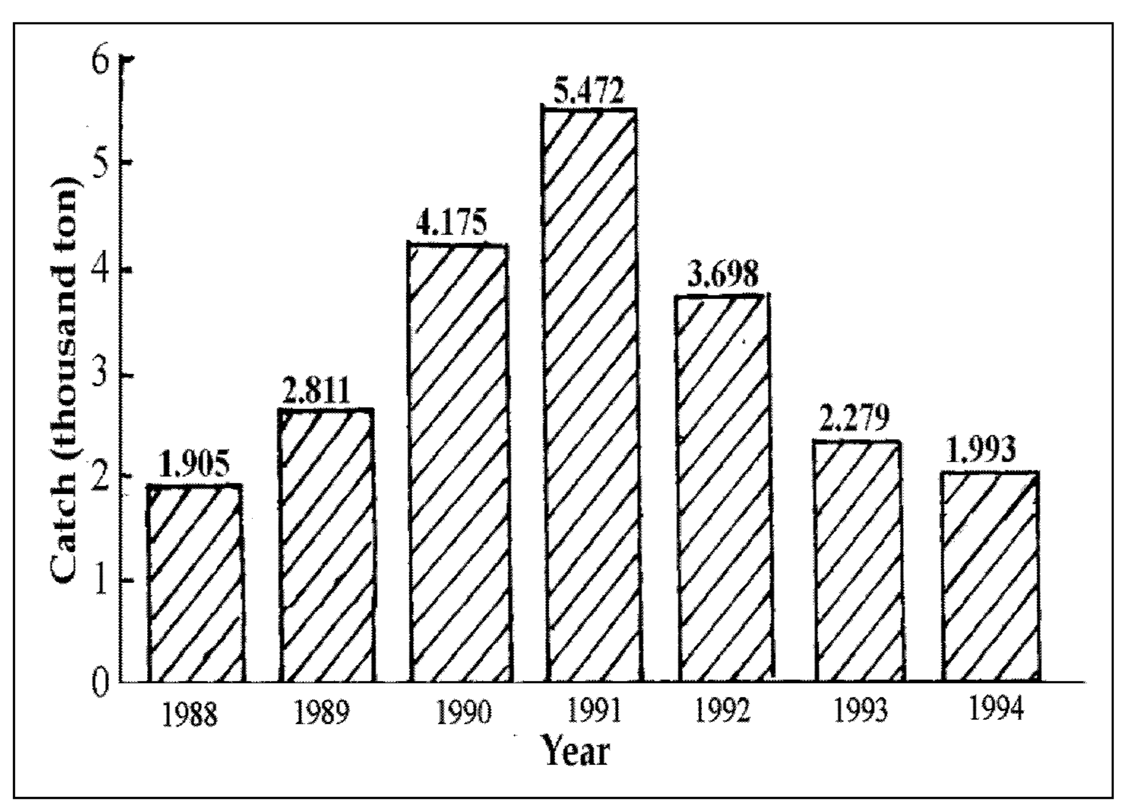


Fig. 243 **Total amount of catch in Khor Kalabsha (Agaypi 1996a).**

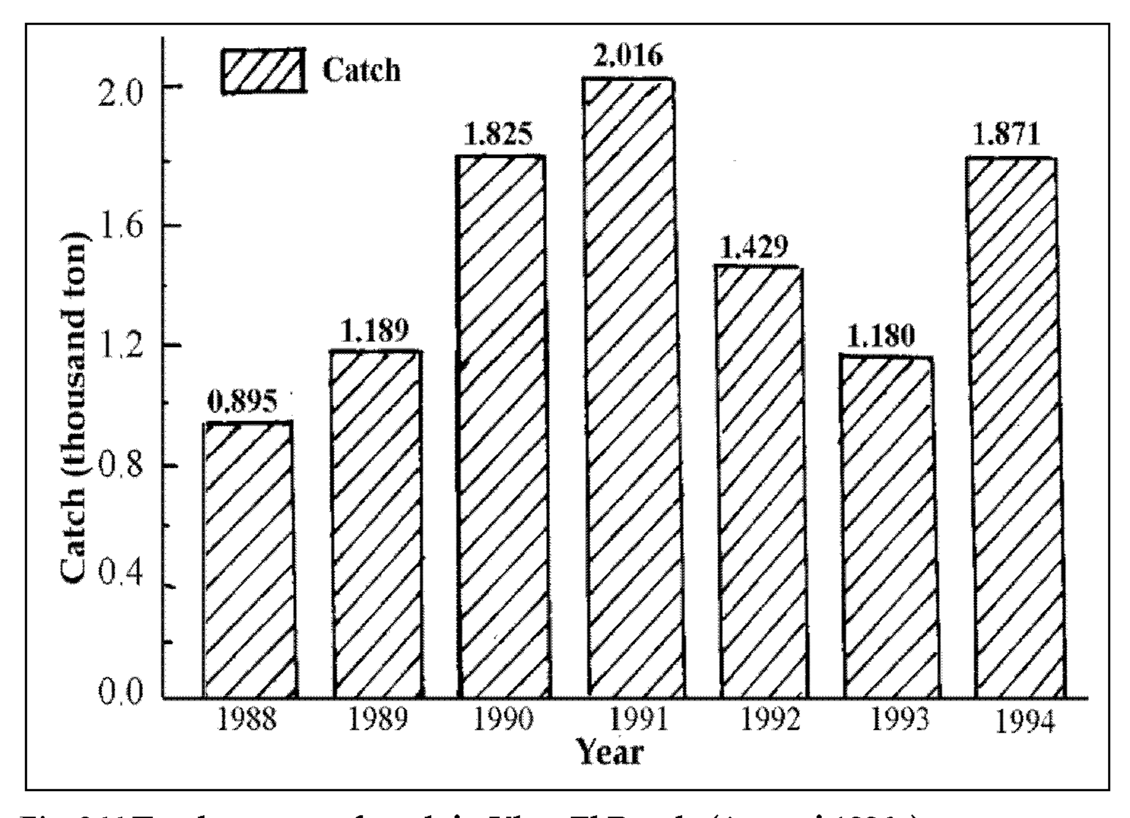


Fig. 244 **Total amount of catch in Khor El Ramla (Agaypi 1996a).**

UTILIZATION OF OPEN WATER AREA

The total fish production from Lake Nasser was only about 19,203 ton in 1998, about 90% being *Tilapia* spp. *(Sarotherodon galilaeus* and *Oreochromis niloticus)* caught from the coastal areas and khors of the Lake. The offshore area (about 80% of the total Lake area) is not well utilized, except for a minor catch of *Hydrocynus* spp., *Alestes* spp. and others.

Attention has been focused on the insufficiently utilized open water area in order to increase fish production of the Lake by introducing a new commercial fish suitable for the Lake environment. The first survey of the new species introduction into Lake Nasser was conducted in 1979 by the Japanese expert Dr. M. Nomura (Professor of Fisheries in Tokyo University), who suggested in 1983 to introduce the following : freshwater herring, silver carp, bighead carp and *Labeo* spp., as they are suitable for the open water area in the Lake. Later on, Nomura suggested not to introduce the freshwater herring, because its fry might inhabit the coastal zone and compete with *0. niloticus* for food (zooplankton) and space. In 1984, Nomura suggested only the introduction of silver carp into the Fishery Management Center (FMC) in Aswan.

Introduction of Silver Carp *(Hypophthalmichthys molitrix)*

First Introduction. Silver carp was originally transported from China to Serw Fish Station in the Delta (National Institute of Oceanography and Fisheries). Nine fish were donated from Serw Fish Station to the Fishery Management Center (FMC) in Aswan. The introduction of silver carp into FMC for the first time was carried out in February 1984. The specimens were small, immature and not suitable for artificial spawning (FMC, 1992).

Second Introduction. Silver carp was originally transported from Hungary in 1982 to Fuwa Hatchery in the Delta. The fish were raised at the Fuwa Hatchery in a clay pond of about 0.2 ha and about 1 m deep. Eight silver carp specimens were introduced from Fuwa Hatchery to FMC in Aswan, where notes on their release into the pond, observation record of fish and scale measurements were recorded (Shimura 1992a).

Induced Spawning of Silver Carp

In 1984 Shenouda (1992) carried out an experiment on induced spawning of silver carp with pituitary injection. Female silver carp grew up to the mature stage but did not ovulate. The latter author attributed the unsuccessful ovulation to low activity of spawners, limited number of mature spawners and

that the trials of hormone injection were beyond the suitable spawning period of silver carp. Later, in 1987 and 1989, Shenouda & Abdel-Shaheed (1993 a and b) carried out experimental studies on induced spawning of silver carp using pituitary gland. After many trials using different doses of the pituitary gland of silver carp, they were successful when using injections of pituitary gland of one dose (3mg/kg) injected twice (0.3 mg and 2.7 mg/kg) within 12 hours interval. The success of spawning was 80% during May and June and 14% during July. The percentage of fertilization was 99.1, 99.6 and 65.7 in May, June and July respectively.

Feeding of Silver carp Fry with Natural and Artificial Feeds

It is well known that silver carp changes its food from zooplankton to phytoplankton as it grows beyond 15 mm in body length (Iwata 1977). The morphological changes in its feeding organs make silver carp able to filter algae. The length of intestine of large fish may range from 7 to 15 times its body length (Sandor *et al.* 1989).

Shenouda (1995b) carried out an experiment on feeding silver carp fry with cultured zooplankton (*Moina* sp.) to find out the effect of different daily rations of live weight on growth of silver carp fry. The experiment was carried out for 20 days, and *Moina* was cultured in a concrete pond (2 x 3 x 0.6m depth). The results of growth, survival rate and food conversion ratio (Table 172 and Fig. 245) indicated that the survival rate decreased with the increase of ration percent, and the best one occurred when using 60% and 80% ration. The best weight increment (16.3 g) was obtained by using 80% ration. After 20 days, the highest growth for silver carp fry occurred, when using 120% ration, followed by 100% ration. The best food conversion ratio was obtained with 60% ration. As during the period of initial fry rearing, the most important factors are survival rate and food conversion ratio. Therefore, for initial rearing of silver carp fry, using live zooplankton like *Moina* sp., the recommendable rations are 60 and 80%.

Abdel-Shaheed (1995a) carried out experimental studies on feeding silver carp fry with natural and artificial food. Thus he fed the fry (0.46 ± 0.13g) on phytoplankton, phytoplankton and artificial food (36% protein) at a feeding ration of 10% of body weight, zooplankton at 120% feeding ration and artificial feed only (36% protein) at 10% ratio of the body weight. The latter author found that the best growth and 100% survival occurred when using phytoplankton together with artificial food (Fig. 246). Thus, it is concluded that the high primary production of open water of Lake Nasser can support large populations of silver carp when reared in net cages.

Table 172 **Results of feeding experiment of silver carp fry on fresh *Moina* sp. (Shenouda 1995b).**

	Daily ration of live weight %					
	20	**40**	**60**	**80**	**100**	**120**
At the beginning						
Number	33	33	33	33	33	33
Total weight (g)	2	2	2	2	2	2
Mean weight (g / fry)	0.061	0.061	0.061	0.061	0.061	0.061
After 20 days						
Number survived	32	32	33	33	15	23
Total weight (g)	4	7	11.9	18.3	9.6	17.9
Mean weight (g / fry)	0.125	0.218	0.361	0.554	0.642	0.778
Weight increment (g)	2	5	9.9	16.3	7.6	15.9
Weight increment (g/fry)	0.064	0.157	0.30	0.493	0.581	0.717
Weight increment (%)	105	257	492	808	952	1175
Food consumption (g)	10.12	25.6	47.1	85.8	130.6	161.8
FCR	4.9	5.1	4.8	5.3	6.8	6.8
% Survival	96.9	96.9	100	100	45.5	69.7

Food conversion ratio (FCR) = feed wt (g)/ live gain (g).

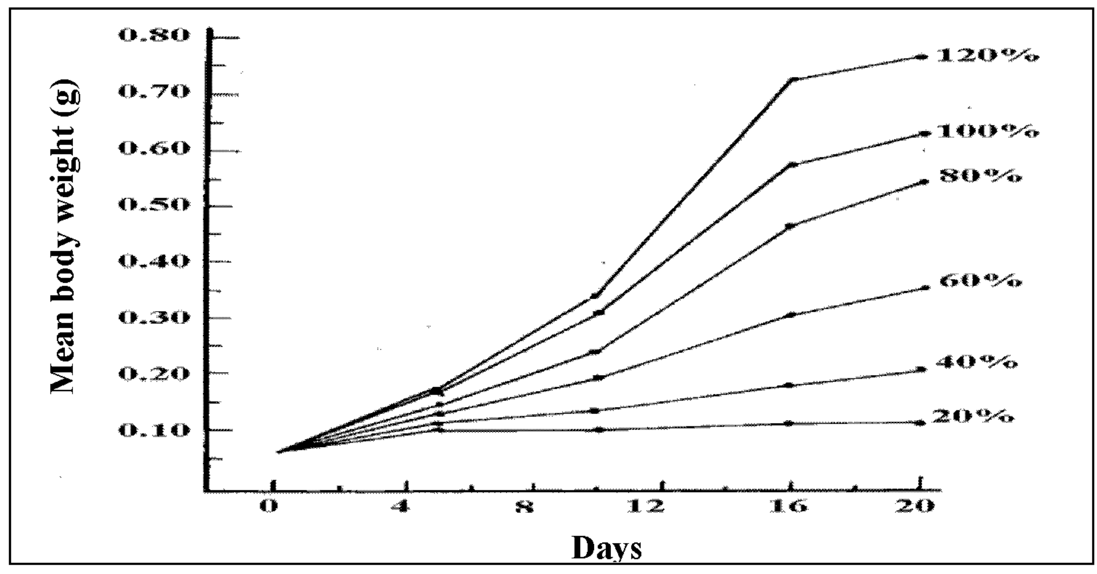


Fig. 245 **The effect of daily ration levels of *Moina* sp. on the growth of silver carp fry (Shenouda 1995b).**

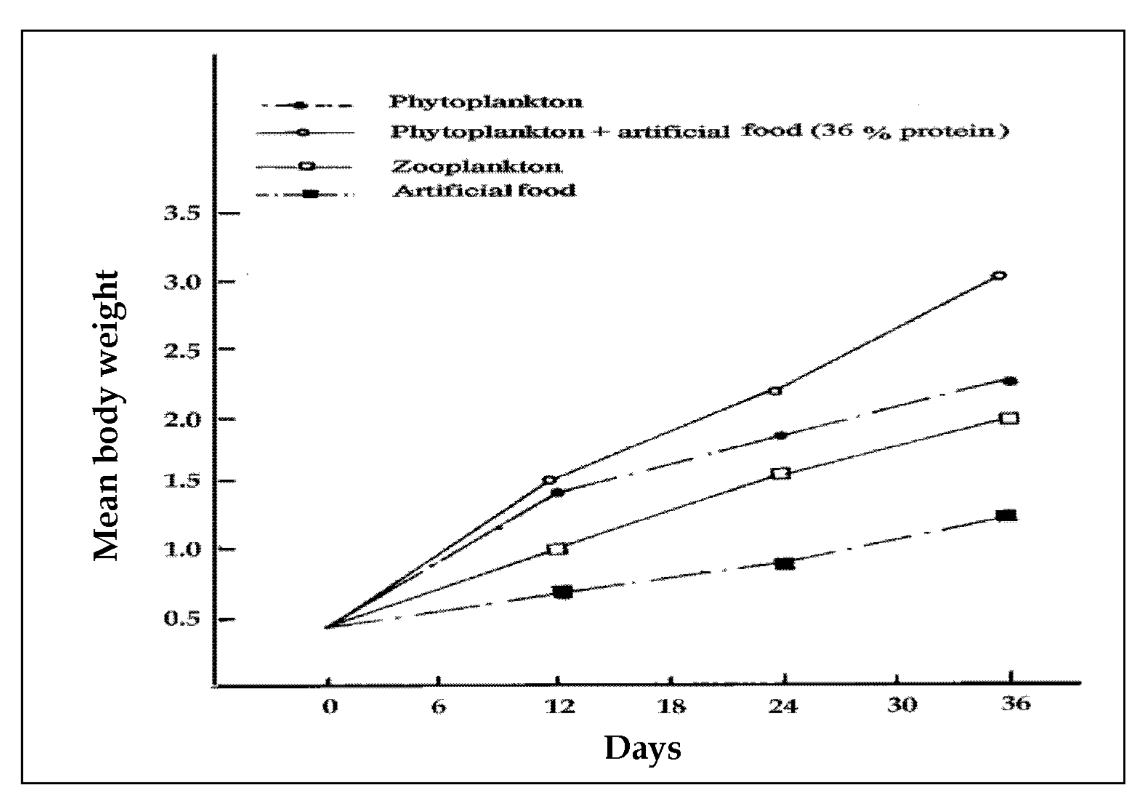


Fig. 246 **Growth of silver carp fry in relation to different kinds of food (Abdel-Shaheed 1995a).**

Food Competition Between Silver Carp and Nile Tilapia

Abdel-Shaheed *et al.* (1996) in their experimental studies on the food of *Hypophthalmichthys molitrix* and *Oreochromis niloticus* reared in cages and ponds at Abu Simbel found that both species feed mainly on the same planktonic organisms (Fig. 247). However, the growth rate of silver carp was slightly higher than that of Nile tilapia. Thus, the daily increment of silver carp ranged between 0.84 and 1.46 g/day, while that of Nile tilapia ranged between 0.71 and 1.05 g/day (Table 173). As a matter of fact, further experiments are needed to elucidate the food competition between both fish species.

Net Cage Culture of Silver Carp

In the Fishery Management Center (FMC) in Aswan, artificial hatching of silver carp, acclimatization and mass production of fingerlings are carried out aiming to utilize the deep open area of the Lake, rich in phytoplankton. However, no stocking of the Lake was done, but silver carp was reared in net cages. The FMC in Aswan succeeded to obtain the technique of silver carp culture in net cages floating in the open area of the Lake, without artificial feeding. Shenouda & Naguib (1993) carried out an experiment to study the effect of stocking density on growth of silver carp in net cages without artificial feeding.

Table 173 Growth of Nile tilapia and silver carp in experimental ponds (Abdel-Shaheed _et al._ 1996) (average in parentheses).

	Nile tilapia			Silver carp		
	Initial B.wt. (g)	**Mean wt. gain (g).**	**Daily increment g/day**	**Initial B.wt. (g)**	**Mean wt. gain (g).**	**Daily increment g/day**
Concrete pond (0 - 0.15ha, water depth 1.2m)	10 - 20 (15)	156.8	0.77	10 – 20 (15)	226.3	1.15
(Amoun Village)	100 – 200 (150)	300.95	0.82	100 – 200 (150)	417.7	1.46
Earthen pond (0 - 0.452 ha, water depth 2.0 m)	10 – 20 (15)	163.75	0.71	10 – 20 (15)	191.7	0.84
(Near new hatchery)	100 – 200 (150)	371.0	1.05	100 –200 (15)	400.7	1.19

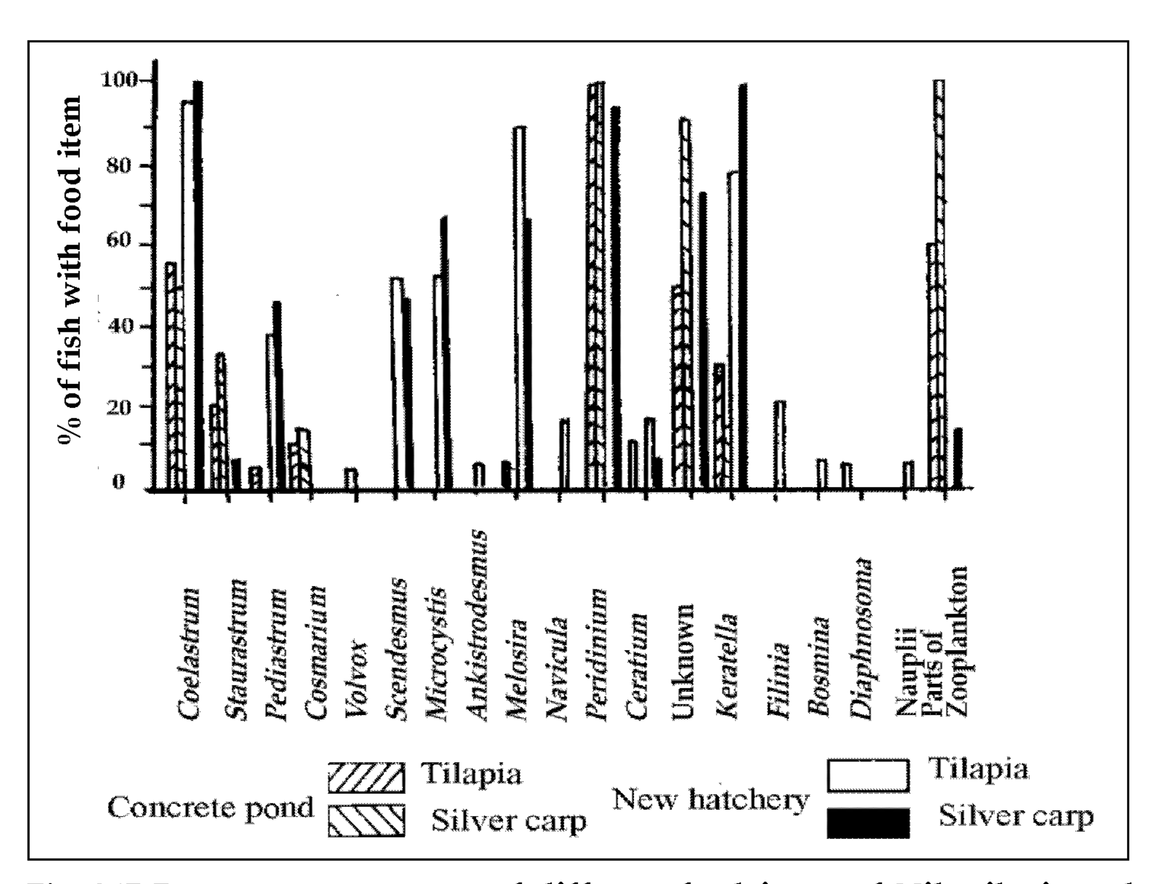


Fig. 247 **Percentage occurrence of different food items of Nile tilapia and silver carp at different sites (Abdel-Shaheed *et al.* 1996).**

Three net cages were used and the capacity of each was 100 m³. The stocking density was 400,700 and 1397 fingerlings with an average weight 28 g in cages no. 1,2 and 3 respectively. After about 15 months the final average weight was 1.62 , 2.02 and 1.23 kg / fish in cages no. 1,2 and 3 respectively (Table 174). The net production for cages was 420.5 , 760.9 and 1081.7 kg respectively (Table 174). The experiment was carried out from March 1990 until June 1991.

Table 174 **Results of silver carp culture in floating net cages without artificial feeds at Abu Simbel in Lake Nasser. (Duration of experiment: 15 months - from March 1990 to June 1991 (Shenouda & Naguib 1993).**

At stocking				At harvest					
Cage No.	Fish No.	Average weight (g)	Total weight (kg)	Fish No.	Average weight (g)	Total weight (kg)	Survival rate (%)	Net production (kg)	
								per cage	per m³
1	400	28	11.2	266	1,620	431.7	66.5	420.5	4.2
2	700	28	19.6	385	2,020	780.5	55.5	760.9	7.6

3	1397	28	39.1	907	1,230	1120.8	64.9	1081.7	10.8

To compare the growth rates of silver carp reared in floating net cages at different regions of Lake Nasser, Shenouda (1997b) located the cages in the northern (Harbour area), middle (Garf Hussein) and southern (Tushka) areas of the Lake. Shenouda (1997b) concluded (Table 175 and Figs. 248-251) that at Tushka (southern area) the highest daily weight gain was attained, being 20.06%, as compared to 2.8 and 16.15% at the northern and middle areas of the Lake. However, it would be better to compare the three areas by using the same stocking density and rearing period.

The suitability of silver carp for net cage culture is not significant without acceptability of its meat to Egyptian people. The reasons why the people do not accept to eat the fresh silver carp, are as follows :

1. There are many fine spines in the muscles. It is too difficult to eat as a daily food and dangerous for children.
2. Its meat is watery and too soft.
3. It has a bad smell, which becomes strong with time after death and storage.
4. Its taste is bitter and strange.

Table 175 **Results of silver carp culture in floating net cages, without artificial feeds, at northern, middle and southern areas of Lake Nasser (Shenouda 19**

Area	Date at:		Average length (cm) at:		Average weight (g) at:		Stocking density (ind./m^2)	Daily weight gain (%)
	stocking	harvest	stocking	harvest	stocking	harvest		
North (Harbour)	April, 1987	Dec., 1987	8.1	17.3	14.4	107	55	2.8
Middle (Garf Hussein)	April, 1987	Sept. 1987	**8.5**	25.7	15	410	83	16.15
South (Tushka)	Sept, 1986	**Dec.,** 1987	13.0	44.5	20	2000	80	20.06

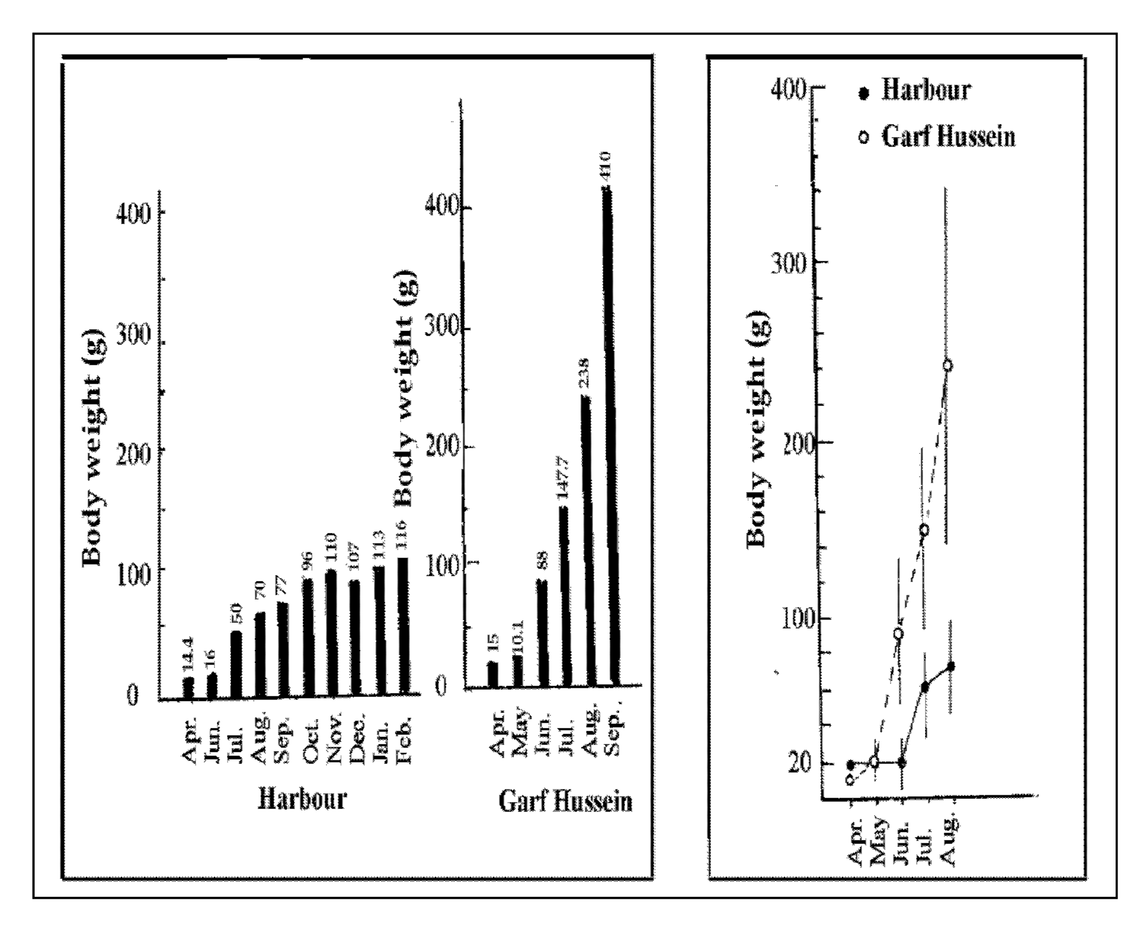


Fig. 248 **Growth of silver carp in net cages at the Harbour area and Garf Hussein (Shenouda 1997b).**

Fig. 249 **Growth range of silver carp in net cages at the Harbour area and Garf Hussein (Shenouda 1997b).**

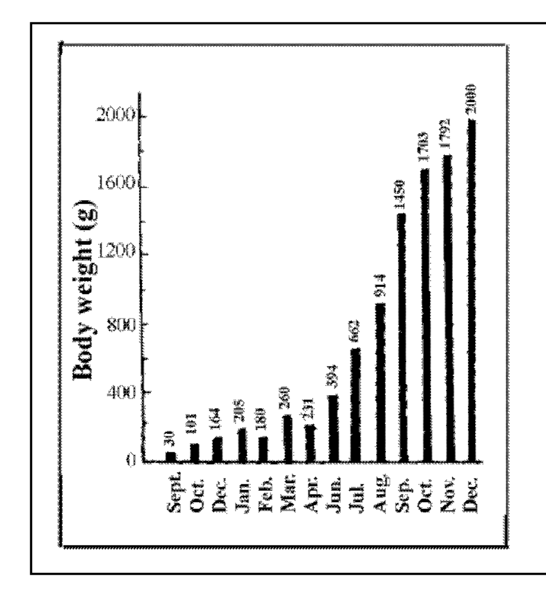


Fig. 250 **Growth of silver carp in net cages at Tushka (duration about 15 months) (Shenouda 1997b).**

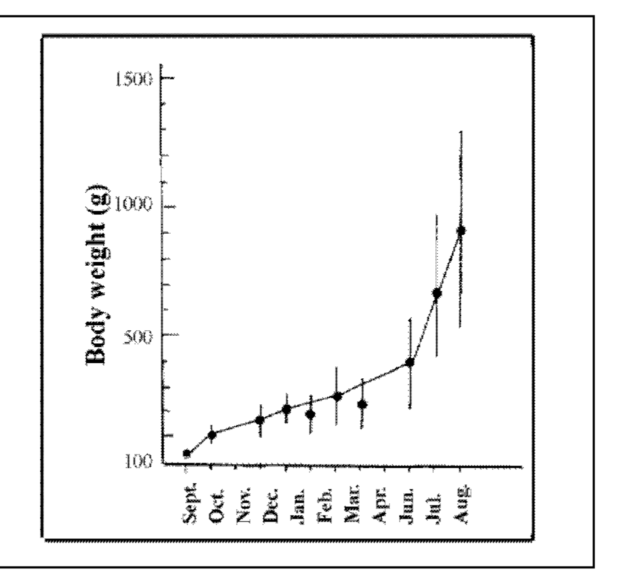


Fig. 251 **Growth range of silver carp in net cages at Tushka. (Shenouda 1997b).**

The fishermen and staff of aquaculture section of Fishery Management Center succeeded to solve the aforementioned problem through processing of salted fish. The Egyptian people accept the salted fish. In the processing, the head, keel of abdomen, and fatty tissue are removed and gutted. The meat is dressed up to exclude the bad smell and bitter taste. Watery and soft meat is improved after dehydration with much salt. The fine spines are not a problem in the eating of salted fish. From the economical point of view, the culture of silver carp in net cages is more effective to control and regulate the amount and timing of supply and fish size at harvest. Furthermore, it seems, as previously mentioned, that silver carp competes with tilapias for food. In addition, escape of certain individuals from cages into the Lake is a possibility, the effects of which are difficult to elucidate. Hence, to take the decision of its culture in cages at Lake Nasser needs further studies.

RESTORING OF INDIGENOUS FISHES

Catch Decrease of some Indigenous Fish Species

As a matter of fact, the catches of some indigenous fish species such as *Labeo* spp., *Barbus bynni, Lates niloticus* and *Bagrus* spp. are sharply decreasing from year to year (Table 176 and Fig. 252). Consequently, the mass production of fry of these indigenous fishes is inevitable. The release of large numbers of fry into Lake Nasser and its khors may be one of the useful measures to increase natural fishery resources.

Table 176 Percentage of catch of indigenous fish species (1966-1995).

Year	Indigenous fish species		
	***Labeo* spp. & *Barbus bynni* (%)**	***Bagrus* spp. (%)**	***Lates niloticus* (%)**
1966	17.69	3.29	0.76
7	21.90	4.90	1.94
8	28.20	2.40	2.89
9	20.40	2.40	6.19
1970	14.40	3.10	7.95
1	13.70	3.60	7.59
2	9.90	3.10	5.41
3	1.98	1.52	3.69
4	0.68	1.01	4.00
5	0.03	0.83	3.59
6	0.00	0.48	2.84
7	1.96	0.36	3.05
8	0	0	0
9	1.23	0.17	1.38
1980	1.24	0.10	1.43
1	1.27	0.06	1.17
2	1.07	0.04	0.96
3	0.64	0.02	0.84
4	0.89	0.02	0.55
5	0.64	0.01	0.52
6	2.50	0.01	1.60
7	2.64	0.01	1.83
8	2.28	0.01	3.40
9	2.00	0.001	4.53
1990	0.41	0.001	2.18
1	0	0	0.82
2	0	0	2.20
3	0	0	3.00
4	0	0	3.00
5	0	0	3.50

Preparation for Artificial Propagation of Fry

Before conduction of mass propagation of fry, the following trials are needed:

i. *Induced spawning.* Techniques of artificial spawning and hormonally induced spawning, for mature brood fish are very necessary for an adequate supply of fry, with which to stock the Lake. Success of induced spawning is strongly dependent on brood fish reaching the right stage of gonadal development.

ii. *Mass culture of plankton.* Live food organisms available for the hatched fry are

quite different, in general, from species to species and also from place to place. Although suitable food organisms for hatched fry are still unknown, preparation for mass culture of phytoplankton and zooplankton is necessary before the initiation of spawning by the brood fish. In general, *Moina* sp. is one of the most suitable zooplankton, since it is relatively easily mass cultured and proved to be effective as food for fry of Nile tilapia and its utilization depends on fish size and species. Mass culture of a rotifer such as *Brachionus plicatilis* is also necessary as an initial live food organism for fry, just after yolk-sac absorption. Few ponds for mass-culture of plankton should be provided.

iii. *Rearing of hatched fry to stocking size.* After feeding with plankton, the fry must be reared up to a suitable stocking size. A large amount of suitable diet should be prepared for that purpose. Some equipment for preparation of diet will be necessary. The dietary ingredients available in Aswan may be evaluated.

iv. *Facilities* . Outdoor ponds, hatchery building, acclimatization ponds, etc., are required to accomplish the above-mentioned requirements.

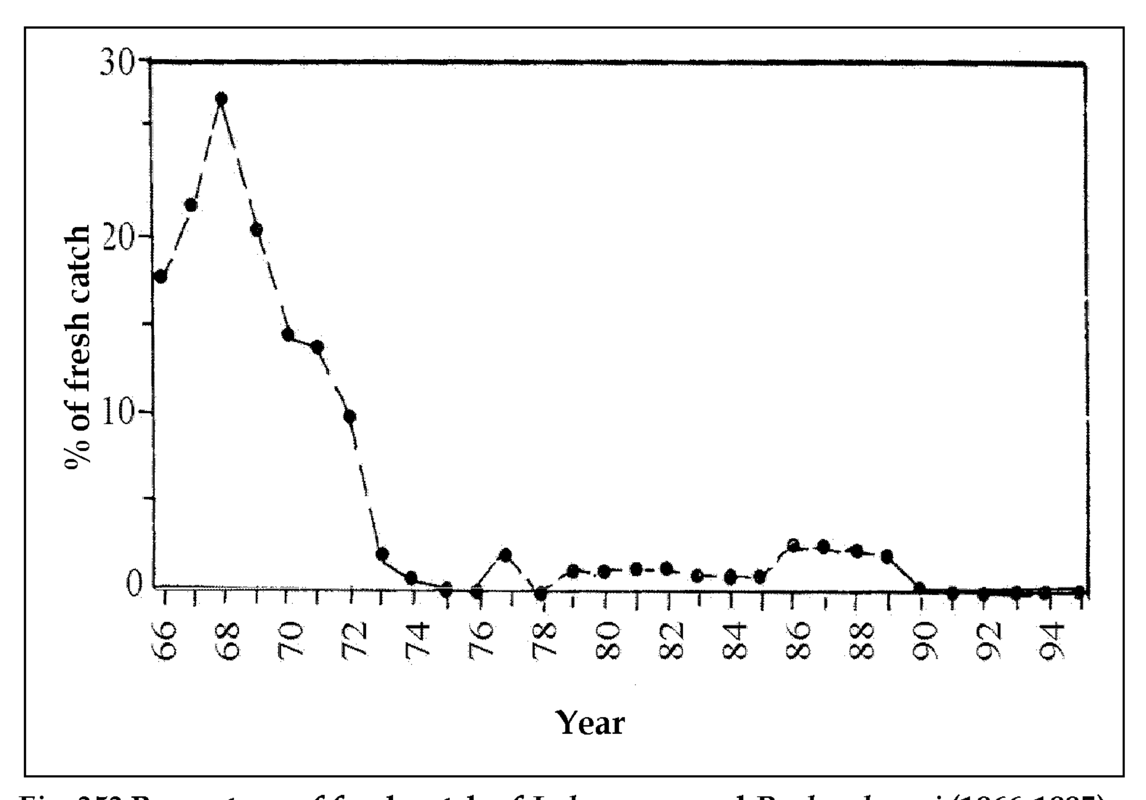


Fig. 252 **Percentage of fresh catch of *Labeo* spp. and *Barbus bynni* (1966-1995).**

Trials on some Important Indigenous Fish Species

Due to the declining of the catch of some important indigenous fish species, and the necessity of giving priority to local species for artifical propagation, so the

Fishery Management Center in Aswan (FMC) carried out experiments on the induced spawning and rearing of fry of *Labeo* spp., *Barbus bynni* and *Lates niloticus* . In view of the importance of these trials, a detailed account of these experiments will be given to evaluate their results and to improve methods of propagation.

a. *Labeo* spp. This species is one of the common and commercially important fish in both River Nile and Lake Nasser, and it is consumed as salted or as fresh fish. However, the catch of *Labeo* species (Family Cyprinidae) is decreasing year after year (Table 176 and Fig. 252). Therefore, restocking of *Labeo* spp. in Lake Nasser, by releasing of fingerlings into the Lake, is necessary for increasing fishery resources.

Abdel-Shaheed (1996) tried to induce spawning of *Labeo* spp. *(Labeo niloticus* and *Labeo coubie)* using pituitary gland injection at different doses, injected once or twice. The trials were unsuccessful and only one female reached stage IV after injection. Injected males, however, produced milt after pressure on belly. It is important to determine the effective dose of pituitary gland to induce the maturation and ovulation of *Labeo* spp. Generally, *Labeo* spp. particularly *Labeo niloticus,* are very sensitive and need great care in selection and handling.

b. *Barbus bynni* (benni). This species is one of the common commercial fish species in Lake Nasser whose annual production is declining (Table 176). Therefore, restocking of benni in Lake Nasser is very necessary for increasing fish resources by artificial propagation, and release of the reared fingerlings into the Lake and khors. From their studies on the maturity and gonado-somatic index (GSI), Abdel-Shaheed *et al.* (1993) found that the most suitable time for artificial propagation of *Barbus bynni* was during spring and autumn, when the highest GSI values were recorded. The technique of the fingerlings production was determined and studies concerning their mass production are in progress.

Rearing experiments of *Barbus bynni* fry in concrete ponds. Abdel-Shaheed & Shenouda (1993b) carried out an experiment on rearing the fry of *Barbus bynni* in concrete ponds, and the results are presented in Tables 177 and 178 and Figs. 253 and 254. The latter authors concluded that for successful rearing, water temperature should be maintained above 24°C.

c. *Lates niloticus* (samoos). *Lates niloticus* is one of the most important fishes in coastal areas of Lake Nasser, whose catch is declining year after year. Hence, fry production of samoos becomes necessary. Shenouda (1993) worked on the induced ovulation of *Lates niloticus* by hormone injection in May 1983. The result of his experiment is given in Table 179. However, further studies are

needed to accelerate the spawning of samoos *(Lates niloticus)*.

Table 177 **Monthly average body weight and length increment of experimentally reared *Barbus bynni* fry (Abdel-Shaheed & Shenouda 1993b).**

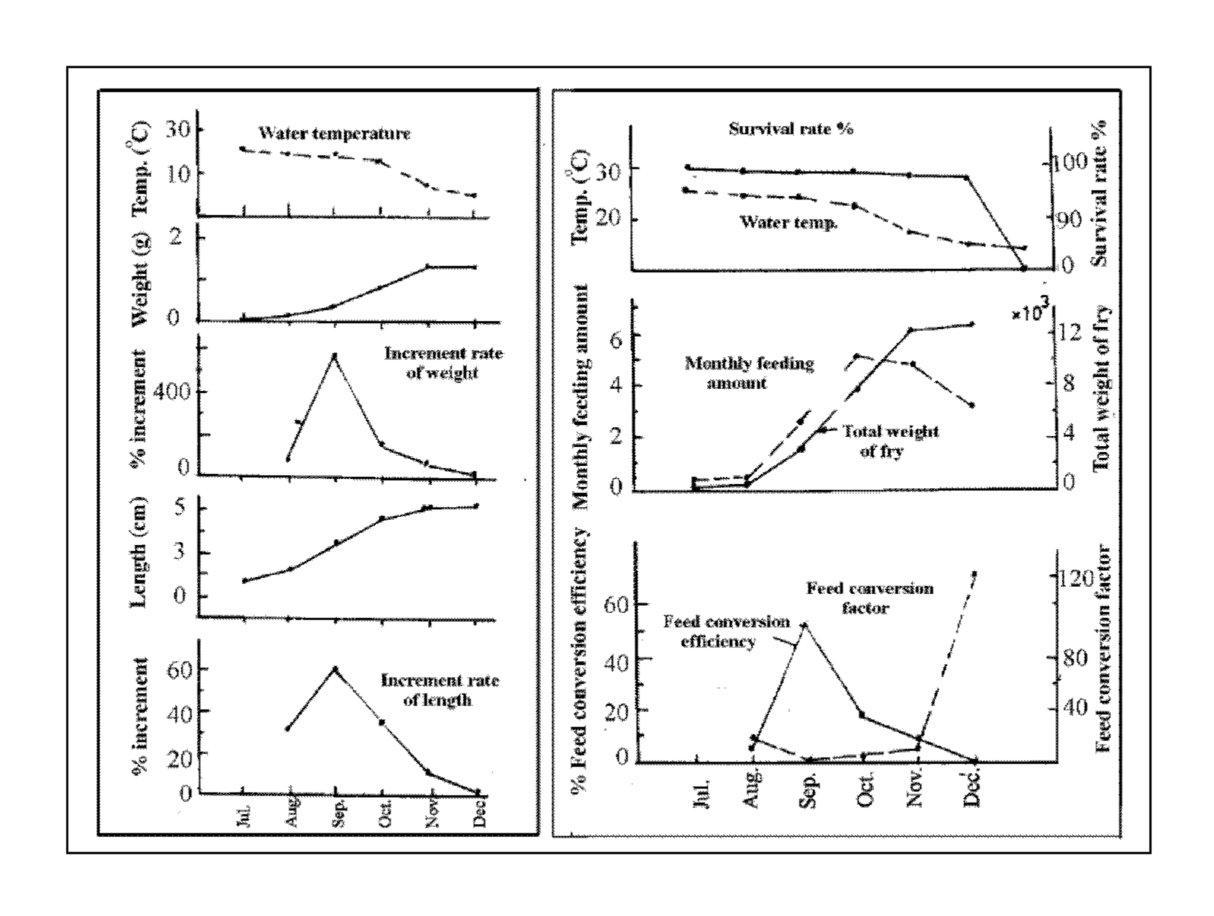
Month	Average body weight (g)	Monthly increment of body weight (g)	Body weight increment (%)	Average total length (cm)	Monthly increment of total length (cm)	Total length increment (%)	Average water temp. (°C)	Dissolved O_2 (ppm)
Jul.	0.03	-	-	1.6	-	-	25.6	9.9
Aug.	0.05	0.02	66.7	2.1	0.5	31.3	24.9	9.2
Sept.	0.33	0.28	560.0	3.4	1.3	61.9	24.3	9.0
Oct.	0.80	0.47	142.4	4.6	1.2	35.3	23.0	10.0
Nov.	1.30	0.50	62.5	5.1	0.5	10.9	17.5	10.6
Dec.	1.41	0.11	8.5	5.2	0.1	2.0	15.2	10.5

Table 178 **Feed conversion efficiency and feed conversion factor of experimentally reared *Barbus bynni* fry (Abdel-Shaheed & Shenouda 1993b).**

	Total No. of fry	Survival rate (%)	Total weight of fry (g)	Monthly feeding amount (g)	Daily feeding rate (%)	Monthly body wt. increment (g)	Feed conversion efficiency (%)	Feed conversion factor
Jul.	1,100	100	330	3,432	40	-	-	-
Aug.	10,300	94	515	5,356	40	185	5.4	18.0
Sept.	10,100	92	3,333	26.000	30	2818	52.6	1.9
Oct.	9,950	90	7,960	51,740	25	4627	17.8	5.6
Nov.	9,500	86	12,350	48,178	15	4390	8.5	11.8
Dec.	9.000	82	12,690	33,020	10	340	0.7	141.7

Table 179 **Experiment on induced spawning of *Lates niloticus* by hormone injection (Shenouda 1993).**

Group	Number of fish		Maturity stage	Dose of injection			
	♀	♂		1st injection	Interval (hours)	2 nd injection	Remarks
A	1	2	IV	HGC 4000 IU/kg	24	HGC 4000 IU/kg	Ovulated but unfertilized
B	1	1	IV	Pit. 50mg/kg	24	Pit. 50 mg/kg	Ovulated but unfertilized
C	2	-	III	HGC 4000 IU/kg	24	-	Ovulated but unfertilized
	2	-	III	**0.9** NaCl	24	-	No ovulation



Water temperature
Temp. (°C)
Weight (g)
% increment
Increment rate of weight
Length (cm)
Increment rate of length
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Survival rate %
Water temp.
Temp. (°C)
Survival rate %
Monthly feeding amount
Total weight of fry
×10³
Feed conversion factor
Feed conversion efficiency
% Feed conversion efficiency

Fig. 253 **Monthly water temperature, body weight, length and increment rate of length of *Barbus bynni* fry (Abdel-Shaheed & Shenouda 1993b).**

Fig. 254 **Variation of water temperature, survival rate, weight, food conversion efficiency and feed conversion factor of *Barbus bynni* fry (Abdel-Shaheed & Shenouda 1993b).**

CONCLUSIONS

For aquaculture development in Lake Nasser three important problems have to be solved. These problems are :

1. Utilization of the coastal area through mass production of Nile tilapia fry, (*Oreochromis niloticus*) with the high growth rate and their release to the khors.

2. Utilization of open water area, through introduction of a new pelagic fish species to feed on the dense plankton populations in this area.

3. Restocking of indigenous fish species.

Mass production of fry of *0. niloticus* is very necessary and a plan to produce one million fry per year is presented. Sufficient and continuous supply of suitable and economical food for Nile tilapia fry is one of the most important items of a tilapia hatchery. *0. niloticus* fry of total length 0.9-1.5 cm prefer *Moina* sp. They feed on not only zooplankton and suspended materials, but also on bottom dwelling organisms such as *Chironomus* larvae. Nile tilapia fry seem to be omnivorous and eat various kinds of food items. Artificial diet composed of scrap tilapia fish meal containing 48.1% crude protein was used as food for *O. niloticus* fry. The best dietary protein level for fry of Nile tilapia was 31.6% at the feeding rate of 10% of body weight per day, and the available scrap tilapia meal is a suitable protein source for Nile tilapia fry diets.

Fry stocking of the khors and applying proper fishery management (prohibiting the use of illegal gear, care to the released fry, no overfishing, etc.) may increase fish production from Lake Nasser.

The offshore area is not well utilized except for some catch of *Hydrocynus* spp, *Alestes* spp. and others. Silver carp *(Hypophthalmichthys nwlitrix)* was suggested to be introduced into Lake Nasser, by using net cage culture. The first introduction of silver carp in 1984, to the Fishery Management Center in Aswan, was from Serw Fish Farm, however, the trial was unsuccessful. The second introduction was from Fuwa Hatchery was successful.

Some trials, for induced spawning of silver carp, were carried out. The last trial for the induced spawning of silver carp by hypophysis injection was in 1989, and the success of spawning trial was 80% during May and June, and the percentage of fertilization was 99.1 and 99.6% in May and June respectively.

Silver carp changes its food from zooplankton to phytoplankton as it grows beyond 15 mm in body length. For initial rearing of silver carp fry, it is advisable to use live zooplankton like *Moina,* the recommendable rations are 60 and 80%. At a later stage, the best growth of silver carp fry occurred by using phytoplankton together with artificial feed. When rearing silver carp in net cages in Lake Nasser, the high primary production can support a large population of silver carp. However, the southern area of Lake Nasser proved to be the best one for culturing silver carp in net cages without artificial feeds. Egyptian people accept the salted silver carp as food. It should be mentioned that precautionary measures should be undertaken not to release silver carp in Lake Nasser, since the impact of such release is unpredictable.

The catch of some indigenous fish species such as *Labeo* spp., *Barbus bynni, Lates niloticus* and *Bagrus* spp. are decreasing from year to year. There is a great need for mass production of fry of these aforementioned fishes. The release of large numbers of their fry into Lake Nasser and khors is one of the useful measures to increase fisheries production.

Before conduction of mass propagation of fry some trials such as: induced spawning, mass culture of plankton, rearing of hatched fry to stocking size and facilities are needed. Trials on some important indigenous fishes such as *Labeo* spp. *Barbus bynni* and *Lates niloticus* have been carried out but until now mass production of fry was unsuccessful. It is always preferred to propagate local species to increase their production without affecting the Lake's ecosystem.

When discussing the possibility of introducing a pelagic fish species into Lake Nasser – to consume the large quantities of plankton in the open water area - with specialists (Dr. R. Lowe-McConnel; Dr. J. Balarin, and Prof. R. Marshall) they suggested the introduction of Tanganyika sardine *Limnothressa miodon* (Boulenger, 1906). This species was introduced from Lake Tanganyika to Lake Kariba in 1967/68, and since spread down the middle Zambezi to Lake Cahora Bassa. Also it was introduced into Lake Kivu. In Lake Kariba, Tanganyika sardine is a major commercial species, where up to 25,000 tonnes per annum may be harvested (Skelton 1993). This species breed in the Lake at about 40 mm or 6 to 8 month age and may attain a maximum of 140 mm total length at about a year. The bulk of the commercial catch is about 30 – 50 mm.

The authors recommend that before introduction of any new species into Lake Nasser, careful and thorough study must be carried out taking in consideration what happened in Lake Victoria after the introduction of *Lates niloticus* which caused disastrous effects on the Lake and its fisheries.

Chapter 12
Amphibian, Reptilian and Avian Fauna

AMPHIBIAN FAUNA

Toads (*Bufo regularis* Reuss, 1834), characteristic of the fauna of the River Valley, started to propagate very intensively and spread all over Lake Nasser in 1970. Population culminated in 1971-1972 with seasonal thousands of mature individuals per/km shoreline (Entz 1980b). In 1973 their numbers decreased rapidly and became almost extinct in 1974 probably because of lack of suitable food (Hussein 1976). However, it seems nowdays that toads are rare in Lake Nasser area. It is reported that *Bufo virdis viridis* Laurenti, 1768, is found in the vicinity of the High Dam (personal communication with Prof. Dr. Mostafa A. Saleh, 1997).

It is probable that at present, with flourishing of agricultural practices along the shores of the Lake, amphibian fauna may flourish. Urgent studies are needed on the amphibian fauna along the Lake on account of the scanty information at present.

REPTILIAN FAUNA

Reptiles are represented in Lake Nasser by three species; the Nile crocodile (*Crocodylus niloticus* Laurentia, 1768), the Nile monitor (*Varanus niloticus niloticus* Linnaeus, 1766) and the Nile turtle (*Trionynx triunguis* Forskal, 1775).

The Nile crocodile (Plates. 63-65)

The Nile crocodile ranked high in ancient Egyptian records, and it was worshipped in many parts of Egypt. In Ancient Egypt, the Greek historian Herodotus mentioned that some dwellers along the Nile treated 'crocodiles' with great kindness embalming and burying them in sacred tombs, when they died. Ancient Egyptians put gold bracelets on the animal's legs. An elaborate city, Crocodilopolis, was built, legend had it, in honour of a crocodile. When the Greek geographer Strabo visited Crocodilopolis, he saw priests open the jaws of a basking holy crocodile and put in roasted meat and cakes and pour in pitcherful of wine mixed with honey. Thousands of crocodile graves were unearthed near Tebtynis, each containing an embalmed crocodile family-male,

female and six young. The graves were prepared perhaps by pilgrims to gain supernatural power.

The Nile crocodile was found along the River Nile even in Rosetta Branch, at El-Rahmaniya village (Flower, 1933). The story of its disappearance in the Nile Valley began in the 1950's, when professional hunters, even from outside Egypt, decimated the stock, and the crocodile skins were sold as an important export item. This enormous destruction brought this species to near extinction. During the 1960's and 1970's only patchy distribution had been seen in some places of Upper Egypt only.

After the construction of the High Dam at Aswan and formation of Lake Nasser, it was a surprise for scientists to observe crocodiles were spreading in the Lake and increasing in number, year after year. This may be because the Lake is now banked on both sides by the desert, and the human population has been thinned, and the environment became suitable and favourable for living and breeding of crocodiles.

The fishermen at Lake Nasser claim that the number of crocodiles are increasing, especially in the southern region and in some of the khors, especially in Khor Korosko which probably contains the highest number, where their number ranges between 20 and 30 individuals per khor. Furthermore, these crocodiles cause damage to the nets and destroy about 100 m of the nets at every fishing operation. Furthermore fishermen, claim that a crocodile can eat about 50 kg of fish per day. For this reason a committee was formed in 1996 by the Egyptian Environmental Affairs Agency to study this problem. One of the goals of this committee was to verify the claims suggested by the fishermen, to find the role of crocodiles in carrying fish parasites as primary and secondary hosts, and to assess their impact on the fisheries of Lake Nasser.

In a recent survey (July-August, 1997) observations on the number and size of crocodiles gathered by fishermen at various khors of Lake Nasser, showed that some khors were preferred by crocodiles, where the number is higher than in other khors. The average number of crocodiles in each of these khors was 2-10 and their size ranged from one to six meters long. The following khors contain the highest numbers of crocodiles: Korosko, Dihmit, El-Soboui, Sayala East, Thomas, Wadi El-Arab and El-Madiq.

On account of the importance of the Nile crocodile to the fisheries of Lake Nasser and its recent spread in khors of the Lake, a detailed review is given on its behavior, growth, reproduction, food and feeding habits, food relations, population dynamics, impact on fisheries and fish-eating birds, as well as conservation.

The crocodilians have been around for nearly 200 million years. There are 21 species including the Nile crocodile. Crocodiles survived while their close kin the dinosaurs died out. Crocodiles have a far complex brain than other reptiles and can learn readily.

The Nile crocodile lives a sophisticated life. Crocodiles are not uricotelic (excreting uric acid) like terrestrial lizards, and so require water for urea excretion.

Behaviour. The Nile crocodile lives in large communities from a few dozens to few hundreds depending on their habitat. Although they live together, they engage in no group behaviour other than large feeding frenzies where all the crocodiles near a large prey converge on it and eat together with surprisingly little fighting.

Territory and ritual rule crocodilian lives. There is a social hierarchy in the crocodile community, and always a big male dominates a river colony. He even controls who basks and where on the beach. Any passing male must lift his head up out of the water and expose his throat, signaling submission, or else face the dominant male fury. When slapping the water with his head, it is one of the ways big males express mood and territoriality. Aggressiveness grows up at the time nearing for his mate to lay eggs.

Crocodiles communicate by their grunts, hisses, chirps and growls, each sound carries a specific message. They also use a "body language" of back arching, bubble blowing and other physical displays. Crocodiles may communicate underwater too, through low frequency warblings inaudible to us.

A big Nile crocodile is cunning enough to stalk a human, strong enough to bring down and dismember a water buffalo, yet gentle enough to crack open its eggs to release their young and carry them in its mouth after hatching. As weapons of offence the formidable fury of trenchant teeth with which the powerful jaws are armed, have not alone to be reckoned with by the victim assailed. The crocodile limbs and claws are relatively weak and incapable of aggressive mischief. The long, compressed tail possesses a terribly effective weapon, wherewith, one swift unexpected side-stroke, it will sweep a smaller animal into water, or deal a blow of sufficient power to fell or disable a man or bullock. Nile crocodiles have been observed, using their long powerful tails to corral a small school of fishes. This disorients the fish and the crocodile has an easy time for catching them. Surprise is one of the most used techniques where a crocodile waits for its prey to come down the water's edge for a drink, when it slowly swims to the shore and lies in wait with just its eyes above the water, a few feet from the animal's head. Then it suddenly lunges out of the water and

latches onto the animal's head with its powerful jaws. Then, the crocodile pulls its prey into deep water where it is drowned.

Crocodiles use their enormous, oar-like tail for swimming. Only their rear feet are webbed, and they are rarely used in movement underwater. On land, the crocodile walks on the short, seemingly weak legs. Nile crocodiles have been known to reach speeds up to 29 miles per hour.

Crocodiles, as might be inferred from the slitlike contour of the eye-pupil, as shown by daylight, are to a large extent nocturnal, displaying their greatest activity, and being in the habit of travelling long distances away from the river banks in search for food or in connection with their migratory or mating instincts, under the cover of darkness. A typical crocodile's day consists of resting, swimming and eating. Just before dawn, they often leave the water to bask in the sun with the mouth open, so that they can dissipate excess heat from inside their mouths in the same way as a dog pants. Near midday the crocodile returns to the water where it will feed if hungry. If upset-for example by the sound of a bullet or motor boat, etc.- a crocodile will go under water and boil the water with bubbles from his nostrils, or he might suddenly shoot half his body straight out of the water and slap his head soundly against the water. Guggisberg (1972) reported that crocodiles may aestivate by digging deep in the mud, to avoid high temperatures.

On rare occasions a lion or leopard pose a threat to adult crocodiles. However, many other enemies are known to crocodiles, raiders for eggs and young. These include the nest robbing Nile monitor lizard, mongooses and other small animals such as wading birds as the six-foot tall goliath heron which attacks the young (Plate 65).

Growth. Crocodile growth is most rapid in early life, showing a mean annual increment during the first seven years of about 265 mm. Thereafter the growth rate decreases progressively, to about an average of 35 mm, per annum at twenty-two years of age. The maximum size attained differs widely according to locality. Specimens appear to attain a maximum length of at least 20 feet.

Reproduction. The Nile crocodile reaches sexual maturity at 8-12 years of age and when around 2.9 -3.3 m in the male and about 2.4 -2.8 m in the female. Cott (1961), however, pointed out that females do not attain sexual maturity until they are at least 19 years old. The breeding season begins in August-October to December-January. Male crocodiles perform elaborate mating displays, much like birds do, and then approaches any respective female. During copulation, which lasts for a minute or two, the pair sinks to the bottom of the lake or river. The female is ready to lay her eggs about two months later. Eggs are usually

laid when water levels are falling. Before laying the eggs, the female chooses a suitable dry sand-bank near the lake's or river's edge, in which it excavates a hole of about two feet deep, and having deposited about 20- 60 eggs, therein, it covers the nest with organic debris creating a constant temperature of about 95°F (35 °C) until they hatch. The mother remains near, or even mounts the top of the nest guarding it without taking any food, may be once a prey coming near it. The mother leaves the area for brief periods to cool during the hottest hours. Both parents jealously guard the nest and repel all intruders until the eggs are hatched. The eggs of the Nile crocodile are small, in the size of the chicken egg, encased in a hard porous calcareous shell. The incubation period lasts for 80 to 90 days. When hatching starts, young crocodiles call from underground. These calls prompt the mother to dig the nest open, cracks the eggs and frees the youngs. The mother waits till all eggs hatch, and then carries the young inside her mouth to a selected place in the river or lake, which is used as a nursery ground. It is believed that the Nile crocodile protects its young for up to two years, after which they are independent, but have to avoid larger crocodiles, which may try to eat them.

Newly hatched crocodiles are weak and fall victims to vultures, hawks, ichneumons and all birds and beasts. They are most vicious and irascible in deposition, hissing and snapping at or laying hold with bull-dog tenacity of a finger or other seizable object. They feed on flies and other insects, then speedily extend to frogs, lizards, fishes or any small animal, which frequent the marches of river or lake banks. Their increased appetites and dimensions requisite such larger prey as sheep, goats, deer, horses or even humans. The hatched young crocodile is about 26-34 cm long and it grows so fast during the first seven years of life, at a rate of about 26.5 cm/year under favourable conditions, then the growth rate decreases progressively.

Food and feeding habits. The diet of crocodiles is extremely varied, and it changes markedly and progressively with the predator's age (Cott 1961). The young feed in shallows and ashore on insects, spiders and frogs. In middle life underwater prey, notably crabs, gastropods and fish, form the main food, old crocodiles feed increasingly upon reptiles and mammals. Corbet (1960) examined 851 crocodiles and found that in specimens up to about one meter in length, which are largely insectivorous, fishes comprise only about 10% of the food, in specimens one to two meters in length fish comprise 30% of the food, and that individuals two to three meters in length rely on fishes for about 60% of their food, with increase in size the importance of fishes gradually declines as other vertebrates become more important. In the whole sample of 851 crocodiles 393 fishes were found in 265 stomachs. The amount of food consumed by crocodiles has been exaggerated in the past. Rough estimates,

based both on field data and on food consumption in zoos indicate that crocodiles just over two meters in length and weighing about 45 kg, at the fish-eating stage, consume their own weight in about 120-160 days. As this weight is not made entirely of fishes, and cichlids usually comprise only a small proportion of those eaten, the effect of crocodiles on the cichlid population of a large lake as Victoria was probably always small (Fryer & Iles, 1972).

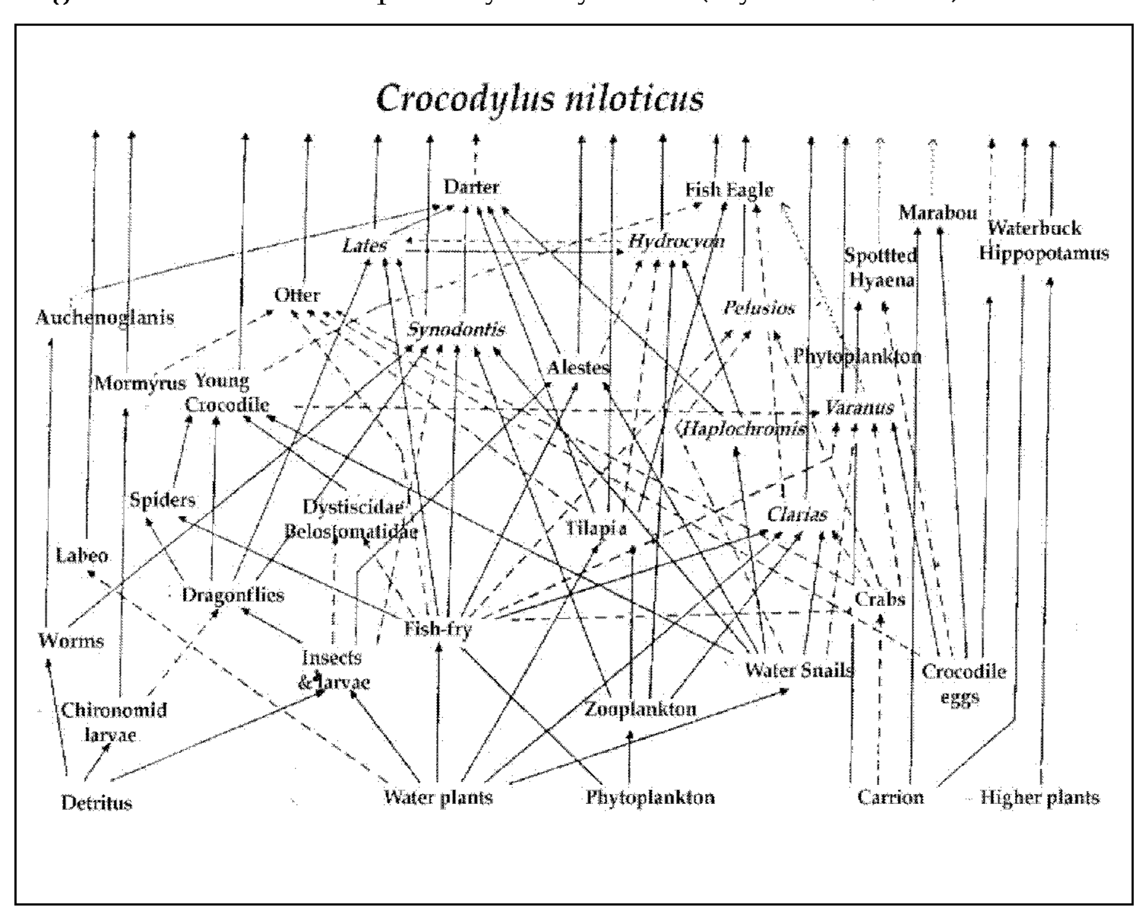


***Fig.** 255* **Diagram showing the food relations of *C. niloticus* to various other members of the fauna: Uganda below Murchison Falls. (Cott 1961).**
[——: links in chains observed in the locality, **- - - - -**: links known to occur elsewhere, **…….**: unformed but probable links].

In a recent survey in 1998, six crocodiles were caught from Lake Nasser, ranging in length from 115 to 467 cm, and their weight ranged from 3.94 to 775 kg. The weight of stomach contents ranged from 0.046 to 8.2 kg. Thus, it seems that food consumption of large crocodiles was overestimated by the fishermen, as the net weight of tilapia fish found in the stomach of the largest crocodile was about 7 kg only.

Food relations of Nile crocodiles

Cott (1961) presented the web of food relationships in which the crocodile plays an essential part (Figs. 255 and 256), which indicated links in the chains. Examination of that part of the food web which primarily concerns

reptiles and amphibians alone reveals sufficient complications, including cases of interspecific competition and reciprocal predation. Thus, the turtle *Pelusios nigricans* and the monitor *Varanus niloticus* both feed extensively upon ampulariid gastropods such as *Lanistes* and *Pila*, which in some localities form a main item in the crocodile's menu at all ages. These three reptiles also prey

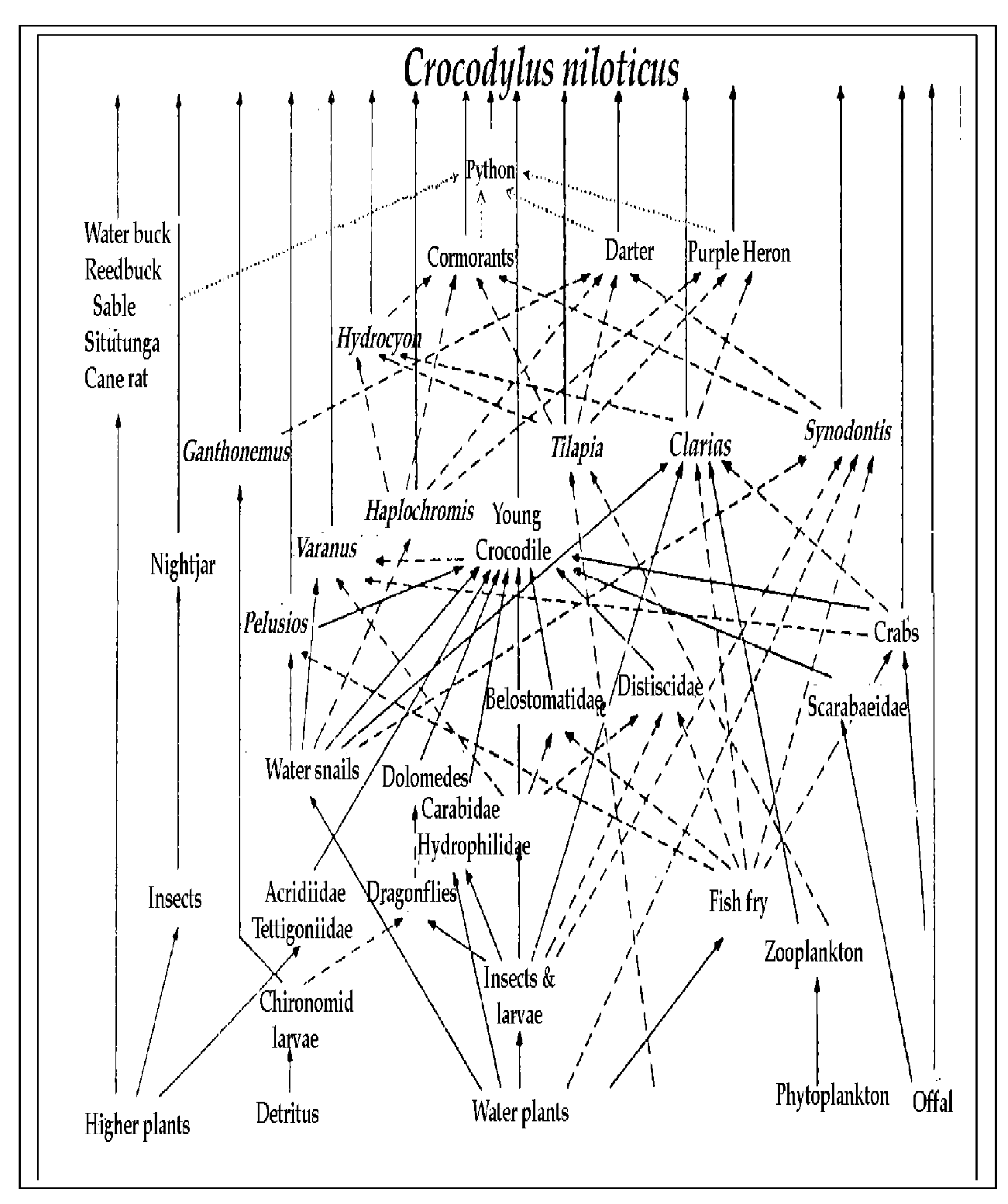


Fig. 256 **Diagram showing the food relations of *C. niloticus* to various other members of the fauna: Upper Zambesi, Barotseland (Cott 1961).**

[——: links in chains observed in the locality, -----: links known to occur elsewhere, …………… : unformed but probable links].

upon the freshwater crab *Potamonautes.* Young crocodiles, and monitors, also eat toads and frogs, and the turtle takes tadpoles, while *Potamonautes* almost certainly includes anura in its generalised diet. Various snakes such as *Naia melanoleuca* and *Chlorophis hoplogaster,* themselves frog-eaters, are also preyed upon by the crocodile. The crabs and crocodiles are both scavengers, readily feeding upon carcasses including those of the crocodile itself. *Varanus* destroys crocodile eggs wholesale, also despoiling the nest of *Trionyx* and (presumably) of *Pelusios. Trionyx* is reputed to prey upon crocodile eggs and newly-hatched young. The crocodile in turn preys upon its enemy *Varanus,* and upon *Pelusios* and *Trionyx*. It also eats the eggs both of the turtles and of its own kind. It rounds off these activities as a cannibal. Fig. 257 indicates a part of the web.

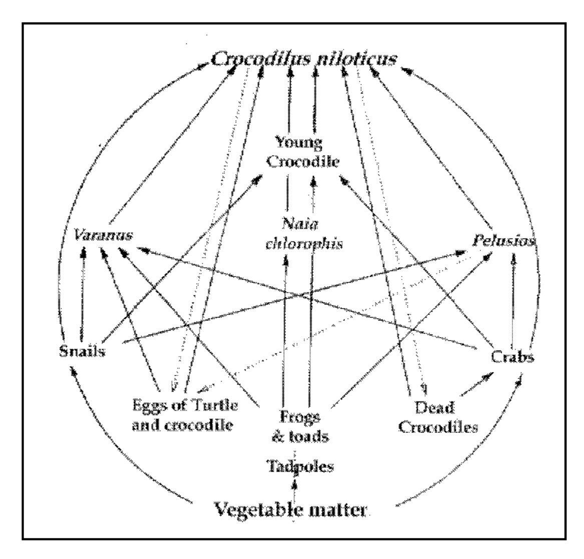


Fig. 257 **Food relations of crocodiles to various other reptiles (Cott 1961).**

Similar complexities are seen at all levels of the food web. Thus, the feeding habit of young crocodiles reveals an intricate network of relationships - the reptiles preying extensively upon secondary predators such as belastomatid bugs and dytiscid and hydrophilid beetles, which in turn take tertiary predators such as dragonfly nymphs, young frogs and fish fry. Young crocodiles also take pisaurid water-spiders whose victims include fish fry and dragon flies- including *Crenigomphus rennei* and *Brachythemis leucosticta* - as observed at Kaiso, Lake Albert. These Odonata are themselves predatory upon other members of the insect fauna, and the situation is further complicated by the crocodile's penchant both for larval and adult dragonflies (Cott 1961).

Parasites: Cott (1961) found that 66% of the crocodiles examined from Uganda harbour nematodes, whose percentages differ according to length groups. Two species of nematodes i.e. *Multicaecum agile* and *Dujardinascaris dujardini* were recovered from the stomach. *Contracaecum* sp. found in certain specimens seems to be derived from fish eaten by the crocodiles, while the other nematodes are specific to crocodiles.

In a recent study during 1998, examination of stomach contents of six crocodiles from Lake Nasser - ranging from 115 to 467 cm length, indicated the presence of some nematode parasites probably *Amplicaecum* spp. (Plate 66); males and females. Some of the fertilized eggs were left to hatch and the larvae were obtained. These parasites are now under investigation for the identification of the species.

Population Dynamics. The Nile crocodile has no clearly defined mode of subsistence. Being a versatile opportunist, it maintains itself and meets varying circumstances with extreme flexibility of behaviour. Its ability to thrive, as an adult, upon prey ranging from crustaceans, molluscs and fish, to waterfowl, reptiles and large mammals, and upon carrion, gives it a unique status in its environment. Apart from the general role it plays as a master predator, it occupies no single niche, but rather many niches - both on land and in the water. Thus, it seems unlikely that food shortage can normally be an important factor in limiting its numbers. Should one food becomes temporarily scarce, the crocodile can turn to another, and in so doing it will exercise a differential pressure upon the shore and freshwater community. Moreover, the marked divergence in prey, feeding habits and habitat of young and old crocodiles - which is even more marked than that often found in a group of congeneric species (Gauss's principle) - must tend to reduce intraspecific competition.

While the crocodile's place at the head of an elaborate system of food chains is unquestioned, heavy mortality, due to predation, nevertheless takes effect in the egg, newly hatched young and immature stages. The maturing population also contains its own internal means of regulation, through cannibalism. Cannibalism also provides an explanation of the segregation of age groups, for the habit tends to keep the young away from open water and basking grounds, among weedy shallows.

Crocodiles and fisheries. Many fishes including the genera: *Protopterus, Barbus, Clarias, Synodontis, Bagrus, Alestes, Hydrocynus, Lates* spp. and others are at some stage predatory on fish, fry, or fish eggs. The aforementioned fish genera together with tilapias are included in the diet of crocodiles (Cott 1961). Thus, it appears that the destruction of crocodiles would be unlikely to benefit fishery interests, and might well be harmful. It is suggested that crocodiles should be maintained to limit the numbers of unwanted cannibal fish such as barbel (*Heterobranchus*). Where crocodiles had been reduced in the Belgian Congo (Zaire), barbel rapidly multiplied (Douglas Hay-cit. Cott 1961).

The importance of the crocodile in relation to the tilapia fishery is clearly seen in the conditions pertaining in Mweru Wa Ntipa, where the reptiles are very plentiful and strictly protected. In this Lake, they tend to be monophagous, feeding extensively upon *Clarias mossambicus,* but apparently not upon tilapiine species which is the main producer of animal protein from vegetable matter, and the important commercial fish. *Clarias* spp. prey heavily upon tilapiine species and in so far as the crocodile keeps *Clarias* spp. in check there can be

little doubt it is beneficial. If, owing to a change of policy, unrestricted hunting were to be permitted, crocodiles would speedily be exterminated, and the consequences might well be disastrous to the fishery.

Young crocodiles play a useful role in the freshwater economy. During the early years of life, crocodiles prey extensively upon giant water-bugs (Belostomatidae), adults and nymphs of dragonflies (Gomphidae, Libellulidae), voracious water beetles (Dytiscidae, Hydrophilidae), freshwater crabs (*Potamonautes*) and upon aquatic spiders (*Dolomedes*). All these invertebrates feed, either as larvae or adults, upon fish fry. Here again the benficial role of crocodiles may be presumed, especially in Uganda, where genera such as *Hydrocynus* and *Limnogeton* are destroyed wholesale. The omnivorous crabs, which form an important part of the young crocodile's diet in the Kafue and Upper Zambezi Rivers, also take their toll of fish. In parts of Zimbabwe, where crocodiles have been shot out of existence, crabs (*Potamonautes*) appear to have increased and reported to be feeding on the nests of tilapia (Cott 1961). Fryer (1959) pointed out that in Malawi *Potamonautes* will readily feed on fishes entangled in gill nets - to which it sometimes causes considerable damage.

Crocodiles and fish-eating birds. Table 180 contains an analysis of prey, by genera, recovered from 246 of fish-eating birds, which were shot in the same waters from which crocodiles were also examined. Figures in Table 181 provide a comparison, in terms of occurrence and number of prey, of the fish-eating habits of waterbirds and crocodiles.

Cott (1961) came to a surprising conclusion that the overall average daily fish consumption of an individual crocodile is less in bulk than that of a White-breasted Cormorant (which consumes at least one kilogram of fish per day). Fish were found in only about one third of the crocodiles, which contained food of any kind, the birds are almost exclusively fish eaters. The mean number of fish per stomach is ten times greater in *Phalacrocorax lucidus* and *Anhinga rufa* than in the crocodile. In the light of these observations, it must be remembered that cormorants and darters themselves constitute the main avian prey of the crocodile in most waters where the reptile's habits have been studied.

Impact of crocodiles on Lake Nasser

Cott (1961) discussed the economic importance of crocodiles as consumers for fish. Although crocodiles eat large amounts of fish, they also prey on other organisms which themselves are predators of fish, and they even eat carcasses. Hence, the crocodile status as major competitors of man for fish is somewhat obscure (Welcomme 1985). Crocodiles play an important role in the ecology of tropical waters (Fittkau 1970, 1973, Fittkau & Klinge 1973) since they are able to maximize the storage and recycling of nutrients of allochthonous origin. Therefore, in places where crocodiles have been eliminated, decline in fish production has been recorded, possibly because of a drop in the primary production based on excreted nutrients (Welcomme 1985).

Table 180 **Prey of White-breasted Cormorant, Pigmy Cormorant and African Darter, in Uganda: (a) Lake Victoria and Victoria Nile above Murchison Falls, (b) Lake Albert and Victoria Nile below Murchison Falls (Cott 1961).**

	Phalacrocorax lucidus		*Phalacrocorax africanus*		*Anhinga rufa*		Total
Locality	**a**	**b**	**a**	**b**	**a**	**b**	
No. of stomachs	**87**	**--**	**61**	**48**	**40**	**10**	**246**
Protopterus	-	-	1	-	-	-	1
Mormyridae	11	-	-	-	1	3	15
Hydrocynus	-	-	-	2	-	-	2
Alestes	-	-	-	8	-	5	13
Barbus	4	-	-	1	-	-	5
Labeo	2	-	-	1	-	-	3
Engraulicypris	355	-	7	6	-	-	368
Discognathus	-	-	-	-	1	-	1
Bagrus	-	-	2	3	-	3	8
Auchenoglanis	-	-	-	2	-	1	3
Clarias	-	-	-	-	1	-	1
Synodontis	3	-	-	12	-	2	17
Lates	-	-	-	13	-	6	19
Tilapia	2	-	-	5	13	7	27
Haplochromis	398	-	139	159	293	47	1,036
Astatoreochromis	1	-	-	-	-	-	1
Mastacembulus	-	-	1	1	-	-	2
Total	**776**		**363**		**383**		**1,522**

More detailed studies are needed on the Nile crocodile in Lake Nasser especially on the biology of reproduction and feeding behaviour as well as population dynamics and to assess its impact on the fisheries of the Lake. It is known in some African lakes, such as Lake Kariba, that the crocodile population consumes about 225 tons of fish per year, amounting to about 10 % of the yield of the fishery (Games 1990).

Conservation

Extensive crocodile population surveys in some areas have contributed to sustainable-yield management programmes, mainly in southern and eastern African countries. Central and western countries have seen much fewer population surveys conducted, and in general most countries have very little information regarding status. After a population decline around the middle of the century due to over-hunting, legal protection has resulted in significant recoveries in several areas, and large populations can now be found (e.g. Botswana, Ethiopia, Kenya, Zambia, Zimbabwe). Humans came into conflict with the Nile crocodile in several areas and this therefore fuels the need to establish more sustainable- yield programmes.

The skin from the Nile crocodile is considered to be 'classic' skin, in that high-quality leather is obtainable without blemish-causing osteoderms reducing its value. It is made into handbags, belts, boots and other accessories.

In Lake Nasser, the increasing number of Nile crocodiles necesssiates management programmes by adopting ecological research on population dynamics, which should provide valuable information for sustainable-yield programmes. Countries which still have certain quotas that can be harvested from the wild are moving towards establishing their own ranching programmes (e.g. Madagascar).

***Table 181* Comparison, in terms of occurrence and number of prey, of the fish-eating habits of waterbirds and crocodiles (*C. niloticus*) [Cott, 1961].**

Locality	Predator	Stomachs containing food of any kind	Stomachs containing fish	Percent. stomachs containing fish	No. of fish prey	No. of fish prey per stomach
Uganda	*P. lucidus*	87	87	100.0	776	8.92
Uganda	*P. africanus*	109	109	100.0	363	3.33
Uganda	A. *rufa*	50	50	100.0	383	7.66
	Total	246	246	100.0	1522	6.19
Uganda	*C. niloticus*	124	44	35.5	81	0.65
N. Rhodesia	*C. niloticus*	549	212	38.6	296	0.54
Zululand	*C. niloticus*	28	9	32.1	16	0.57
	Total	701	256	37.8	393	0.56

The Nile monitor (Plate 67)

The Nile monitor (*Varanus niloticus niloticus* Linnaeus, 1766) is found mostly in the more uninhabited areas of the Lake shores. The adult attains 170 cm or more in length. Although, more or less, aquatic in its habits, it is frequently seen hunting for its food along the banks of the Lake and can move long distances overland and during periods of drought in some khors of the Lake. The Nile monitor is carnivorous and the young feed on insects and frogs, while the large individuals feed mainly on fish, young crocodiles and their eggs. From the strongly carnivorous instinct, which it manifests in confinement, eating rats and mice with avidity, it probably preys on the field-rat, the burrows of which are so plentiful along the shores of the Lake, and may likewise devour some lizards such as *Mabuia* sp. and *Chalcides ocellatus,* which are found in similar situations. Recently, Saleh (1997) pointed out that the Nile monitor is a highly aquatic species, never found far from water. The latter author mentioned that it feeds on fishes, but may venture out of water to feed on rodents, snakes, lizards and birds.

However, little reliable information has yet been placed on record regarding the habits of this lizard, and more detailed studies are needed especially on its reproduction, population dynamics and feeding behaviour.

The Nile turtle (Plate 68)

The Nile turtle; *Trionynx triunguis* (Forskal, 1775), used to inhabit the Nile, but is much more numerous south of Aswan (Saleh 1997). It is usually caught in Lake Nasser -mostly from the southern region - and is sold in the fish market. It feeds on fish, Nile crabs and possibly snails. Eggs are usually deposited in spring on sand banks, possibly of the khors, and left to hatch by the suns' heat. Until now no detailed study on its ecology, distribution and population density is carried out in Lake Nasser. Such studies are urgently needed.

AVIFAUNA (Plates 69-78)

The bird fauna of Aswan region is much poorer than in the north towards the Delta, or in the south towards Sudan. This, may be, because Aswan area is extremely hot and arid, and it is believed that only very adaptable species can live there, but the fact is that there are also waterbirds in the Nile and its islands and on the shores of Lake Nasser. Moreover, Aswan area is an important route of migrating birds coming from Europe in autumn, either to stay in the area and "enjoy" the winter sun, or to go further south in deep Africa. However, many investigators have reported that migrant birds, especially waterbirds, use now the water of Lake Nasser and its adjoining khors to a greater extent than before the High Dam construction.

Meinenger & Mullié (1981) recorded 19 species of waterbirds from Lake Nasser (Table 182). Later on Meinenger and Atta (1994) surveyed the Lake during winter 1989/90 and they recorded 47 species in the Lake khors based on observations made only from the shores (Table 183). Abdel-Azeiz (1993) recorded 122 species of birds during 1988-1991 in the Nile Islands and Wadi Allaqi.

Records of birds other than waterbirds include the Egyptian Vulture (*Neophron percnopterus*), Marsh Harrier (*Circus aeruginosus*), Ospery (*Pandion haliaetus*), Eagle Owl (*Bubo bubo*), Pallid Swift (*Apus pallidus*) and Martin (*Riparia riparia*).

Meinenger & Atta (1994) mentioned that the number of birds seen in the northern part of Lake Nasser was surprisingly low. Many birds can be missed because of the dendritic shoreline and the locally dense vegertation. Resident breeding species include the Egyptian Goose, Kittlitz's Sand Plover, Spur-winged Plover and African Skimmer. Vast numbers of migratory palaearctic waterbirds were observed during winter months making it of global importance for some species of waterfowl. There is also a smaller influx of African waterbirds during summer months.

Meinenger & Atta (1994) pointed out that the orinithological importance of Lake Nasser is only partially known and more data are urgently needed. The Lake holds potentially important orinithological areas. Lake Nasser might well

be an important staging area for many species during migration, e.g. White Pelican *Pelecanus onocrotalus* and White Stork *Ciconia ciconia.* Lake Nasser area is the only area where African Skimmer (*Rynchops flavirostris*) and African Pied Wagtail (*Motacilla aguimp*) are known to breed in Egypt (Baha El Din 1999). The area's original breeding bird community which probably included African Palm Swift *Cypselus parvus,* and Fulvous Babbler *Turdoides fulvus,* disappeared after filling of the Lake started.

Table 182 **Number of waterbirds recorded at Lake Nasser by Meinenger & Mullié (1981)**

Species	Number
Phalacrocorax carbo	2
Bubulcus ibis	21
Egretta garzetta	160
Ardea cinerea	55
Alopochen aegyptiacus	38
Anas crecca crecca	20
Anas acuta acuta	5
Anas clypeata	4
Fulica atra atra	61
Charadrius hiaticula tundrae	1
Charadrius pecuarius allenkbi	8
Charadrius alexandrinus alexandrinus	1
Hoplopterus spinosus	2
Calidris minuta	22
***Charadrius / Calidris* sp.**	38
Tringa totanus totanus	1
Actitis hypoleucos	1
Larus ridibundus	865
Chlidonias niger niger	118

Impact of waterbirds on fisheries.

Mekkawy (1998) pointed out that predation of birds may affect fish populations indirectly through competition for food, or directly through piscivory. Thus, invertebrates constitute an important component of diet of adult dabbing ducks, black ducks, divers, herons, smews, gulls and kingfishers (Danell & Sjoberg 1980, EIFAC 1989). Erickson & Kautsky (1992) observed that the African Open-billed Stork (*Anastomus lamelligerus*) feeds on molluscs during the period of low water level in shallow regions. During this period, the storks are distributed in relation to the sites where *Mutela dubia,* the most preferred mussel, is abundant. Studies on the avifauna of Lake Nasser (Meinenger & Mullié 1981, Meinenger & Atta 1990, 1994, Abdel-Azeiz 1993) showed that all the above mentioned groups of fish and invertebrate eating birds are represented in the Lake and its vicinity except divers and smews. Mekkawy (1998) emphasized the importance of competition of these birds in the highly productive Lake Nasser in spite of the fact postulated by EIFAC (1989) that the relative importance of invertebrates in the diet of birds increases with Lake productivity.

Table 183 **Counts of waterbirds and raptors in Lake Nasser, winter 1989/90 (Meinenger & Atta 1994).**

Species	English name	Total	Old Dam Lake 20+22/1	Island of Kalabsha 24/12+27	Garf Hussein 29/1	W. Allaqi SE 24/1	W. Allaqi SW 25/1	Turgimi 25/1	Abu Simbel 21/1
Tachybaptus ruficollis	Little Grebe	10	-	-	10	-	-	-	-
Podiceps nigricollis	Black-necked Grebe	117	20	3	90	-	4	-	-
Phalacrocorax carbo	Cormorant	1	-	-	-	-	-	-	1
Plecanus onocrotalus	White Pelican	1	-	-	1	-	-	-	-
Ardeola ralloides	Squacco Heron	6	-	-	-	2	4	-	-
Bubulcus ibis	Cattle Egret	25	15	-	-	10	-	-	-
Egretta garzetta	Little Egret	79	50	1	10	-	15	3	-
Ardea cinerea	Grey Heron	31	5	5	13	3	3	2	-
Ardea purpurea	Purple Heron	4	-	1	-	-	3	-	-
Plegadis falcinellus	Glossy Ibis	27	26	-	1	-	-	-	-
Platalea leucorodia	Spoonbill	68	-	-	35	32	-	1	-
Alopochen aegyptiacus	Egyptian Goose	88	-	20	50	5	9	4	-
Anas penelope	Wigeon	2600	1700	-	900	-	-	-	-
Anas crecca	Teal	330	-	-	100	120	100	10	-
Anas platyrhynchos	Mallard	10	10	-	-	-	-	-	-
Anas acuta	Pintail	220	20	-	150	30	20	-	-
Anas clypeata	Shoveler	750	400	150	100	80	15	5	-
Aythya ferina	Pochard	2250	1600	-	220	320	100	10	-
Aythya nyroca	Ferrugineous Duck	10	4	-	-	-	6	-	-
Aythya fuligula	Tufted Duck	2740	1400	120	1000	170	50	-	-
Milvus migrans	Black Kite	105	50	20	3	2	-	-	30
Neophron percnopterus	Egyptian Vulture	44	-	13	3	20	-	-	8
Circus aeruginosus	Marsh Harrier	7	-	-	2	3	-	2	-
Buteo rufinus	Long-legged Buzzard	1	1	-	-	-	-	-	-
Pandion haliaetus	Osprey	2	1	1	-	-	-	-	-
Falco tinnunculus	Kestrel	5	-	2	1	-	1	-	1
Faclo peregrinus	Peregrine	1	1	-	-	-	-	-	-
Gallinula chloropus	Moorhen	16	6	-	-	10	-	-	-
Fulica atra	Coot	950	400	-	100	300	150	-	-
Himantopus himantopus	Black-winged Stilt	59	-	-	25	20	4	10	-
Cursorius cursor	Cream-coloured Courser	8	-	-	8	-	-	-	-
Characrius dubius	Little Ringed Plover	36	30	-	-	-	6	-	-
Charadrius alexandrinus	Kentish Plover	18	16	-	2	-	-	-	-
Hoplopterus spinosus	Supr-winged Plover	15	-	1	-	14	-	-	-
Chettusia leucura	White-tailed Plover	6	-	-	-	-	6	-	-
Calidris minuta	Little Strint	170	150	-	20	-	-	-	-
Gallinago gallinago	Common Snipe	1	-	-	-	1	-	-	-
Limosa limosa	Black-tailed Godwit	5	5	-	-	-	-	-	-
Tringa erythropus	Spotted Redshank	2	-	-	-	-	2	-	-
Tringa nebularia	Greenshank	9	3	-	6	-	-	-	-
Tringa ochropus	Green Sandpiper	2	-	-	-	2	-	-	-
Actitis hypoleucos	Common Sandpiper	13	10	3	-	-	-	-	-
Stercorarius pomarinus	Pomarine Skua	1	-	1	-	-	-	-	-
Larus ridibundus	Black-headed Gull	1750	500	500	700	-	-	-	50
Larus fuscus	Lesser Black-backed Gull	1	-	1	-	-	-	-	-
Chlidonias hybrida	Whiskered Tern	300	-	-	300	-	-	-	-

Ceryle rudis	Pied Kingfisher	1	-	1	-	-	-	-	-

Table 184 **Estimates of amounts of fish (kg) consumed by pelicans in the Ruwenzori National Park during 1969 (Din & Eltringham 1972).**

	White Pelican	Pink-backed Pelican	Total (kg)
Lake Edward	436825	143817	580642
Lake George	374561	131785	506346
Lake Nyamusingire	22623	19190	41813
Kazinga Channel	12069	21559	33628
Breeding Area	--	63190	63190
Nestlings	--	22173	22173
Total (kg)	**846078**	**401714**	**1247792**

Previous studies on the indirect impact on fish populations indicate that it is potentially very large and that studies in Africa and Europe show that the amount of fish taken by birds may surpass the amount taken by the fishery (Welcomme 1985, EIFAC 1989). Thus, in Senegal River, Reizer (1974) showed that cormorants and pelicans consumed 70,000 ton/year as compared to a fish catch of about 50,000 ton/year. Estimates of amounts of fish consumed by pelicans in the Ruwenzori National Park during 1969 in kg are presented in Table 184 (Din & Eltringham 1972).

Din & Eltringham (1972) pointed out that the food of pelicans is exclusively fish. The white pelican takes mainly large *Tilapia*, and *Haplochromis* spp. and fish fry to a lesser extent. The Pink-backed Pelican feeds largely on fish fry, but *Tilapia* and *Haplochromis* spp. are frequently taken and by weight are more important than the fry. However, the tilapias are smaller than those taken by the White pelican. Ecological separation between the two species is achieved through these differences in their feeding behaviour.

The latter authors estimated that the White Pelican takes 1201 g and the Pink-backed Pelican 776 g of fish each day. The total amount of fish eaten by both species from Lake George during 1969 was calculated to be 591 and 709 kg. This is small (3 %) compared with the estimated total fish production of the Lake but quite appreciable (12.7 %) as a proportion of the total fish caught by man.

Various authors assessed the food consumption by different species of birds (Geiger 1957, Tjomlid 1973, Din & Eltringham 1974, Nilsson & Nilsson 1976, Cook 1978, Meyer 1980, Linn & Campbell 1986). According to such assessments, consumption can vary almost 100-fold between small birds (such as adult

Kingfisher with an average 36 -46 g weight), which consume about 18 g of fish per day, and large birds as the White Pelican (with a weight up to 11 kg) which can consume 1600 g of fish per day (EIFAC 1989).

Reizer (1974) pointed out that the daily ration of fish consumption is 500 - 1000 g for a heron, 1000 -2000 g for a pelican and 250 g for a Kingfisher *Ceryle rudis*. McIntosh (1978) found that the European cormorant *Phalacocorax carbo* eats about 650 -700 g of fish per day. The Pelican (*Pelecanus onocrotalus*) is known as the heaviest predator to any species of fish, while the Cormorants *Phalacrocorax* sp. feeds mainly on *Barbus* sp. (Schulten & Harrison 1975).

Abdel-Azeiz (1993), in her study during 1988 -1991 recorded 122 species of birds in the Nile Islands and Wadi Allaqi. Most of the recorded species are migrants or birds of passage. Out of the 122 recorded species, only 32 species were previously recorded in Lake Nasser (Meininger & Mullié 1981, Meininger & Atta 1990, 1994, Kinzelbach 1990, Goodman & Meininger 1989). From the previous studies on the avifauna of Lake Nasser and its vicinity 17 bird species (Table 185A) are fish-eating -11 species were previously recorded in Lake Nasser. Mekkawy (1998) estimated roughly the diet impact of most of these species (with an average daily ration of 620 g of fish per day) to be about 2885.6 ton per year (Table 185A). This figure represents 8.3, 11.01, 14.65 and 14 % of the total fish production during 1981 (with the highest fish production), 1992, 1995 and 1996 respectively equivalent to a loss of about 536.4 kg per km of shoreline (total shoreline 5380 km at 160 m water level). Mekkawy's estimation (1998) needs to be verified taking in consideration that out of the 17 species of fish-eating birds recorded in the Lake and its vicinity, one species is a resident breeder, five are resident breeders and winter passage visitors, while 11 species are winter visitors. Furthermore, four bird species in Mekkawy's original list (1998) i.e. Little Bittern, Great White Egret, White Stork and Black-headed Gull are not fish-eating birds (Tharwat 1997). The latter author mentioned 44 species of birds in Lake Nasser area, 19 species are fish-eating (Table 185B & Plates 67-78).

The impact of piscivorous birds on fisheries of Lake Kariba was studied by Hustter (1991), who showed that about 12 -16 % of the commercial inshore fisheries is eaten by only two birds, the Reed Cormorant (*Phalacrocorax africanus*) and the Darter (*Anhinga melanogaster*). They eat about 20 and 11 % of their body weight daily, respectively, and their prey is to a large extent made up of small-bodied fish species. In their survey of aquatic bird species in Lake Kariba Okaeme *et al* (1989) recorded 70 bird species, most of which inhabit the

littoral zone and open water with *Oreochromis niloticus* and *Sarotherodon galilaeus* and *Chrysichthys nigrodigitalis* forming part of their diet.

Table 185 (A) **List of fish-eating birds of Lake Nasser and their estimated fish requirements (ton) per year in the whole Lake (Mekkawy 1998).**

Family/ species	Common name	Status*	Fish required**
Podicipedidae			
Tachybaptus ruficollis ruficollis	**Little Grebe**	RB-WV	**42.0**
Podiceps nigricollis nigricollis	**Black-necked Grebe**	WV	**1.6**
Phalacrocoracidae			
Phalacrocorax carbo sinensis	**Cormorant**	PV-WV	**22.4**
Ardeidae			
Botaurus stellaris stellaris	**Bittern**	WV	**8.1**
Ardea cinerea cinerea	**Grey Heron**	CP-PV-WV	**120.2**
Ardea purpurea purpurea	**Purple Heron**	PV-WV	**16.0**
Ardea goliath	**Goliath Heron**	RB-PV	**1.6**
Ardea ralloides	**Squaccco Heron**	RB-PV-WV	**51.3**
Ciconiidae			
Mycteria ibis	**Yellow-billed Stork**	PV	**83.4**
Ciconia nigra	**Black Stork**	PV-WV	**9.6**
Threskiornithidae			
Plegadis falcinellus	**Glossy Ibis**	PV-WV	**1.6**
Pandionidae			
Pandion haliaetus haliaetus	**Osprey**	RB-PV-WV	**16.0**
Gruidae			
Grus grus grus	**Crane**	PV-WV	**12.8**
Laridae			
Larus genei	**Slender-billed Gull**	RB-PV-WV	**1.6**
Sternidae			
Sterna repressa	**White-cheeked Tern**	MB	**6.4**
Alcedinidae			
Alcedo atthis atthis	**Kingfisher**	CB-WV	**19.2**
Ceryle rudis rudis	**Lesser Pied Kingfisher**	RB-WV	**365.5**

***Abdel-Azeiz (1993) : CB= causal breeder; MB= migrant breeder; PV= passage visitor; WV= winter visitor; AV= accidental visitor, RB=resident breeder (**Mekkawy, 1998).**

Mekkawy (1998) pointed out that in view of their social organization, roosting and feeding behaviour, gulls are probably the most important species, which play a role in influencing the trophic state of lakes and reservoirs (EIFAC 1989). In Lake Nasser, at least two species of gulls are recorded i.e. Black-headed Gull, *Larus ridibundus* and the Slender-billed Gull, *Larus genei,* both species are passage winter visitors, the latter, however, is a resident breeder. Tharwat (1997) pointed out that the former species feed on invertebrates and small animals. The assessment of the impact of populations of both species on Lake Nasser needs to be studied. Assessment of the effects of roosting gull populations on nutrient inputs has been studied by various investigators (Leentvaar 1967, McColl & Burger 1976, Gould 1977, Gould & Fletcher 1978, Beveridge *et al.* 1982). Impacts towards the increase of pH, conductivity, organic matter, BOD, nitrogen, phosphorous, coliform bacteria and plankton have been reported. The role of birds which nest and feed on water bodies, in determining

the nutrient status of a water body, depend on the feeding behaviour, seasonal abundance and community organization of the species.

Furthermore, other birds which congregate in large numbers for extended periods and which forage for fish in the immediate vicinity of the Lake, are most likely to have a marked effect on the nutrient status through importation of allochthonous materials.

Hence, the impact of the bird fauna - either those that inhabit the Lake or its vicinity - must be studied in detail. The relationships between species composition and abundance and the trophic status of the Lake must be assessed. Furthermore, there is a possibility that some bird species act as primary or secondary hosts for fish parasites, whose prevalence increased in recent years.

THREATS. There appears to be no major threats to birds in Lake Nasser area. However, some impact is known from both land reclamation for agricultural purposes and sport hunting. In addition, fisheries may cause some impacts. Shooting of waterbirds is reported to take place regularly during winter by visiting European hunters, who take both game and non-game (protected) birds (Baha El Din 1999).

Legal Status. Until now, Lake Nasser is not protected. However, a portion of Wadi El-Allaqi has been declared a protected area by Prime Minister's Decree in 1989.

Table 185 (B) **Birds of Lake Nasser area recorded by Tharwat (1998). (Plates 69 - 78)**

Species	English name	Arabic name
* ***Phalacrocorax carbo***	Cormorant	غراب البحر
* ***Anhinga melanogaster***	Darter	زق
* ***Plecanus onocrotalus***	White Pelican	بجع أبيض
* ***Plecanus rufescens***	Pink-backed Pelican	بجع رمادى
* ***Botaurus s. stellaris***	Bittern	واق
Egretta ibis	Cattle Egret	أبوقردان
* ***Egretta garzetta***	Little Egret	بلشون ض
* ***Mycteria ibis***	Yellow-billed Stork	لقلق أصفر المنقار
* ***Ciconia ciconia ciconia***	White Stork	لقلق أبيض
Threskiornis a. aethopicus	Sacred Ibis	أبو منجل قدس
Alopochen aegyptiacus	Egyptian Goose	وز مصرى
* ***Tadorna ferruginea***	Ruddy Shelduck	أبو فروه
* ***Anas qurquedula***	Garganey	شرشير صيفى
* ***Aythya ferina***	Pochard	حمراى
* ***Milvus m. migrans***	Black Kite	حداية سوداء
* ***Haliaeetus vocifer***	African Fish Eagle	عقاب السمك الأفريقى
Neophron p. percnopterus	Egyptian Vulture	رخمة مصرية
Micronisus gabar	Gabar Goshawk	باز جبار
* ***Gallinula c. chloropus***	Moorhen	فرخة الماء
Fulica a. atro	European Coot	ر
Grus g. grus	Crane	كى رهو أو غرنوق)
Burhinus senegalensis inornatus	Senegal Thick-Knee	كردان سنغالى
Chettusia leucura	White-tailed Plover	زقزاق أبيض الذنب
Phalaropus lobatus	Red-necked Phalarope	فلاروب أحمر العنق

Table 185 **Cont.**

Larus ridibundus	Black-headed Gull	نورس أسود الرأس
Chlidonias n. niger	Black Tern	خطاف أسود
Pterocles c. coronatus	Crowned Sandgrouse	قطا متوج
Streptopelia s. senegalensis	Palm Dove	يمام بلدى
* ***Bubo bubo ascalaphus***	Eagle Owl	بعفه
Athene noctua spilogaster	Little Owl	أم قويق
Caprimulgus a. aegyptius	Egyptian Nightjar	سد ا مصرى البخا)
* ***Alcedo a. atthis***	Kingfisher	صياد السمك
Alaemon alaudipes alaudipes	Hoope Lark	مكاء
Galerida cristata maculata	Crested Lark	قنبره متوجه
Ptyonoprogene o. obsoleta	Pale Crag Martin (Rock Martin)	سنونو الصخر الباهت
Motacilla aguimp vidua	African Pied Wagtail	أبو فصاده أبقع
Oenanthe l. leucopyga	White-crowned Black Wheatear	ابلق اسود ابيض الرأس
Oenanthe l. lugens	Mournig Wheatear	ابلق حزين
Oenahe monacha	Hooded Wheatear	ابلق أبو طاقيه
Prinia g. gracilis	Graceful Warbler	فصيه هازج)
Rhodopechys g. githagineea	Trumpeter Finch	زمير زمار - طبال)
* ***Ardea cinerea cinerea***	Gray Heron	بلش ن رمادى
* ***Ardea purpurea***	Purple Heron	مالك الحزين حجنـ)
* ***Ardea goliath Cret.***	Goliath Heron	بلشون جبار مر)

* Fish-eating birds.

CONCLUSIONS

Nowadays amphibian fauna are rare in Lake Nasser area. However, it seems that with flourishing of agricultural practices along the shores of the Lake amphibian fauna may flourish, and so urgent studies on this fauna are needed.

Reptiles are represented in Lake Nasser by three species; the Nile crocodile (*Crocodylus niloticus* Laurentia), the Nile monitor (*Varanus niloticus niloticus* (Linnaeus) and the Nile turtle (*Trionynx triunguis,* Forsk.). During the 1950's professional hunters decimated the stock of crocodiles in the River Nile, that brought this species to near extinction. After formation of Lake Nasser, crocodiles spread in the Lake and are increasing in number, year after year, especially in the southern region and khors. Fishermen are claiming now that crocodiles cause damage to their nets as well as destroy tilapia nests in the Lake shores and feed on large amounts of fish, that may cause impact on the fishery of the Lake. Furthermore, the role of crocodiles in the Lake must be studied especially their population density, effect on primary production based on excreted nutrients and impact on fisheries..

The Nile monitor is found mostly in the more uninhabited areas of the Lake shore. It is carnivorous, feeds mainly on fish as well as young crocodiles and their eggs, lizards, snakes, rodents and even birds.

The Nile turtle used to inhabit the Nile, but now it is much more numerous in the southern region of Lake Nasser. It feeds on fish, Nile crabs and possibly snails.

With the increase in prevalence of infestation of common Lake fishes with parasites, there is a possibility that the Nile crocodile, the Nile monitor and Nile turtle may act as intermediate or final hosts of these parasites that may account for the increased prevalence of fish parasites. Further detailed studies for these species are needed, especially on their population dynamics, their distribution and feeding behaviour.

Since Lake Nasser filling, it began to be a suitable habitat for water-birds, especially that the area is an important route for migratory birds coming from Europe in autumn, either to stay or as a station to go further south in Africa. In 1981 Meinenger & Mullié recorded 19 species of waterbirds. During winter 1989/90 Meinenger & Atta (1994) recorded 47 species of birds. In 1988/91 Abdel-Azeiz (1993) recorded 122 species in the Nile Islands and Wadi Allaqi in the vicinity of the Lake, among them there were 17 species of fish-eating birds.Tharwat (1998) mentioned the presence of 44 species of birds in Lake Nasser area, among which 19 species are fish-eating birds.

Baha El Din (1999) pointed out that during January and February 1995 over 56,000 waterbirds were counted on about 20% of the Lake. Thus the total number of waterbirds wintering in the entire Lake could be in excess of 200,000, making it one of the most important wetlands in Egypt. Most abundant of these were: Black-necked Grebe, White Pelican, Tufted Duck, Northern Pochard, Northern Shoveler, Wigeon and Black-headed Gull.

Characteristic breeding birds in Lake Nasser include: Egyptian Goose, Black Kite, Senegal Thick-Knee, Kittilitz's Plover, Spur-winged Plover, Crested Lark and Graceful Prinia. Lake Nasser is the only area where African Skimmer and African Pied Wagtail are known to breed in Egypt. During the summer months there is a significant influx of Yellow-billed Stork and Pink-backed Pelican into Lake Nasser (Baha El Din 1999). The area's original breeding bird community which includes African Palm Swift, and Fulvous Babbler disappeared after filling the Lake.

Estimation of the amount of fish consumed by fish-eating birds amounted to 2885.6 ton per year (Mekkawy 1998, i.e. about 14% of the total Lake production in 1996). It seems that this figure is overestimated, especially some of the fish-eating birds with high fish consumption - included in this estimation do not eat fish; and most fish-eating birds are only winter visitors.

The impact of the avifauna on Lake Nasser must be studied in detail especially the relationship between species composition and the trophic status of the Lake. Furthermore, studies are needed to find out the possible relationship of the bird fauna and the fish parasites, probably some bird species may act as hosts for some fish parasites. The high prevalence of infection by the nematode *Contracaecum* (as larvae) of various fish species in Lake Nasser, is attributed to the increase of waterbirds in which the adult stage lives in the proventriculus. A thorough study of this parasite: its species, life cycle, effect on fish is needed.

Chapter 13
Lake Nasser and other Man-made African Reservoirs

Large reservoirs are generally used for many purposes, which include flood control, water storage for irrigation; generation of electricity, industrial or domestic use, and regulation of flow for navigation. During the 1950's and 1960's many reservoirs were constructed in Africa, the largest four of them are Lake Volta Ghana (1964 - Fig. 258), Lake Kainji on River Niger (1963 - Fig. 259), Lake Kariba on Zambezi River, Zambia (1958) and the High Dam Lake on the River Nile, Egypt / Sudan (1964) (Table 186).

The High Dam differs from other dams in a number of characteristics. It is the biggest rockfill dam in the world. It has an impervious core, with a grout curtain that extends 180 m under the core to meet the rock, and a horizontal upstream impervious blanket. The length of the dam at the top is 3,600 m, while the width is 980 m at the bottom and 40 m at the top and its height above the river bed level is 111 m.

The High Dam Lake (6,276 km^2 area) is one of the largest man-made lakes in Africa and second in area after Lake Volta (8,845 km^2). Also, Lake Volta has a greater volume (165 km^3) than the High Dam Lake (156.9 km^3), while the mean depths of both lakes are almost similar (Table 187). Comparing Lake Kainji with the other three lakes, it has the smallest area and volume, being 1280 km^2 and 15.8 km^3 respectively. Moreover, the mean depth of Lake Nasser is twice deeper than Lake Kainji. Lake Kariba has an area of about 5,364 km^2, while its volume is about 156.5 km^3.

On the other hand, the High Dam Lake has a much more irregular shoreline (9,250 km), so its perimeter is much longer than that of Lake Volta (5,300 km). Therefore, "Shoreline Index" values for the High Dam Lake are 2-5 times greater than those for Lake Volta and the other two lakes (Table 187).

PHYSICO-CHEMICAL CHARACTERISTICS

Water temperature. Comparing the water temperature profile of Lake Nasser with that of other Lakes (Table 188), the depth profiles clearly reveal that the

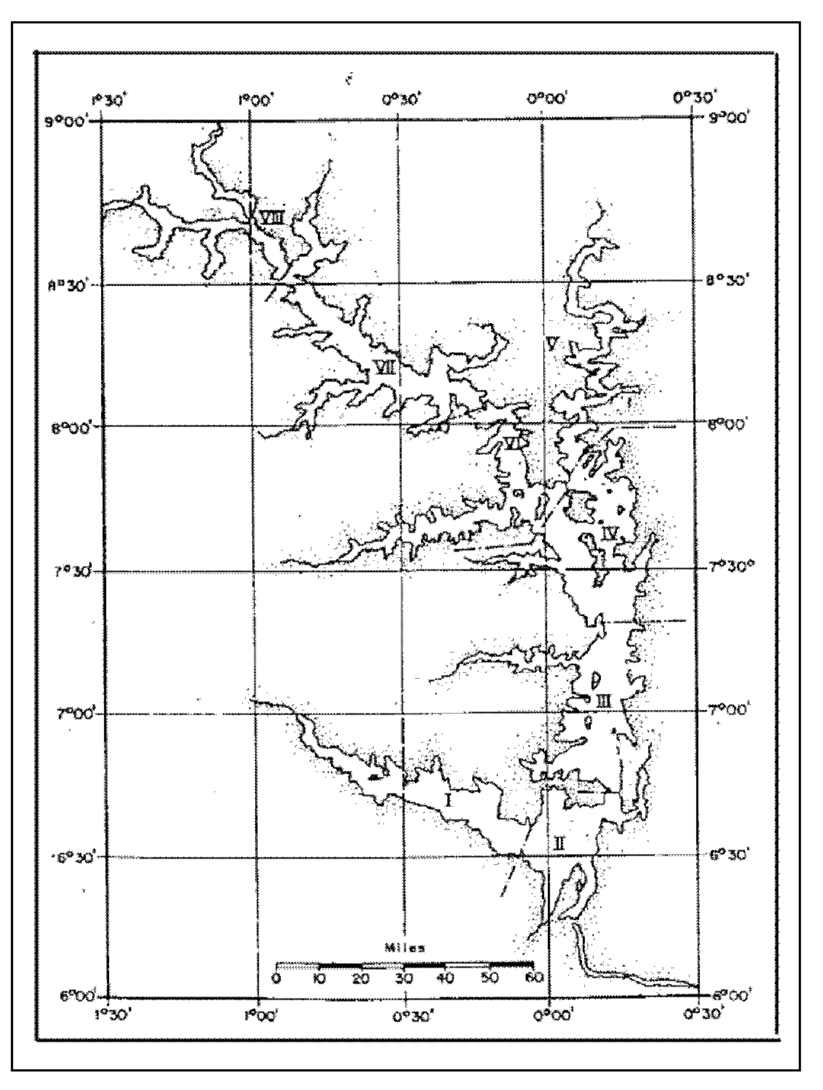


Fig. 258 **Map of Volta Lake, showing the eight strata.**

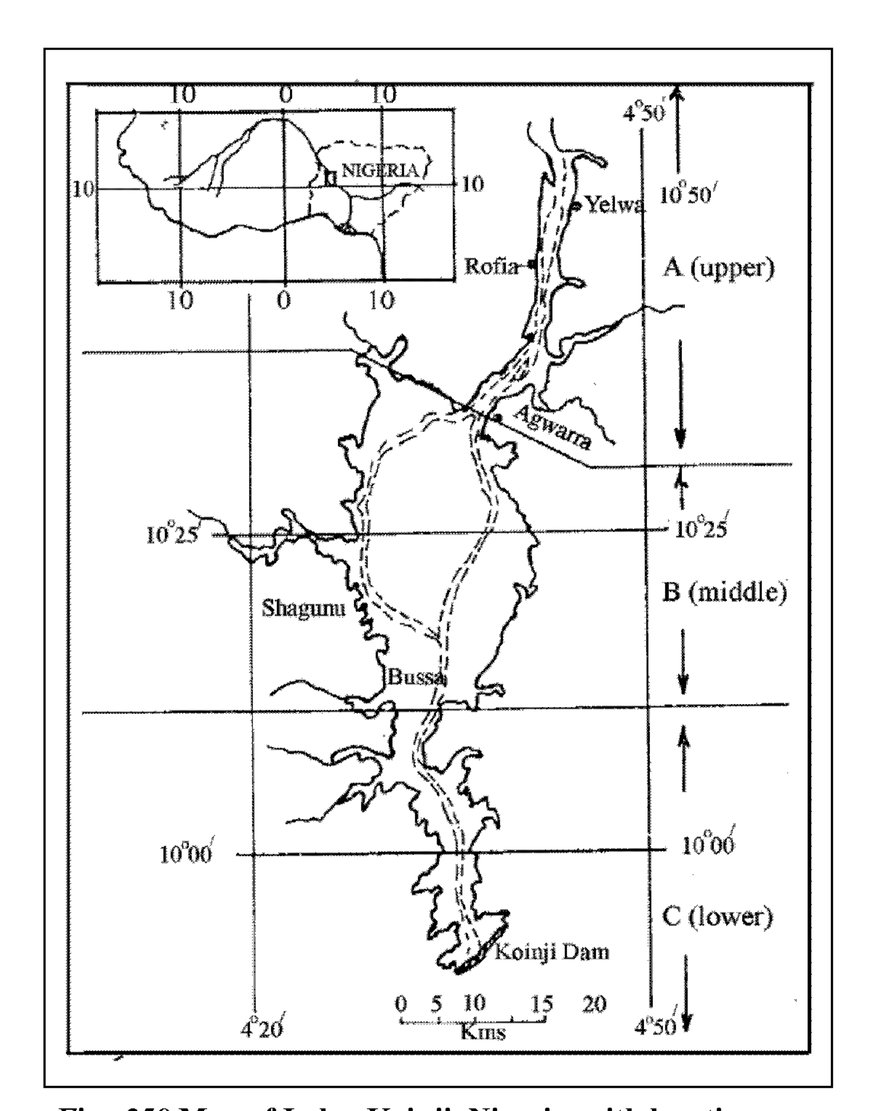


Fig. 259 **Map of Lake Kainji, Nigeria, with location map insert, showing the original path of the River Niger and the three basins.**

Table 186 **General comparison among the four African reservoirs.**

Characteristics		L.Kariba	L. Nasser/ Nubia	L. Kainji	L. Volta
Geography	Country	Rhodesia-Zambia	Egypt/Sudan	Nigeria	Ghana
	Latitude	16° 28'-18° 04 S'	23°58'-20° 27' N	9° 30'-10°35' N	6°15-9°10N
	Longitude	26° 42'-29° 03' E	30° 35'-33° 15' E	4° 20'- 4°40' E	1° 40'W-0° 20'E
	Altitude, m a.s.l.	485	180	142	85
	Vegetation type	forest - wooden savannah	desert	forest+Guinean Savannah	forest-Guinean savannah
Meteorology	Climate (Köppen)	BSwh	BWhs	Aw	Amw-Aw
	Mean air temp. (°C)	24.3-24.7	(24)	(26.5)	26.4-27.8
	Abs. min temp. (°C)	2.8	5	(mean) 14.1 (Dec. Feb.)	20 (mean 25.7)
	Abs. max temp. (°C)	40.6	48	(mean) 39.0 (Mar. - May)	(mean) 28.0
	Rainfall year (mm)	610	--	660-1352 (May - Sep.)	890-1712
	Gross evapor. (mm)	2500-3600	3824	1500-2000	1398
Dam	Site	Kariba	Aswan	Kainji	Akosombo
	Closed in:	December 1958	May 1964	August 1968	May 1964
	Normal water level in	1963	1975	1968	1968
	Hydroelectric max. capacity (Kw)	1500	2100	960	882

Table 187 **Main morphometric features and potential yield of the four African Lakes.**

Parameter	Kariba	Nasser/Nubia	Volta	Kainji
Length (km)	320	482	400	137
Width, mean (km)	19.4	13.0	6.8	9.3
Width, maximum (km)	40	20	24	24
Depth, mean (m)	29.2	25	18.6	12.3
Depth, maximum (m)	120	130	75	50
Shoreline length (km)	2164	9250	5300	720
Shoreline development	8.3	31.2	14.5	5.7
Area (km^2)	5364	6276	8845	1280
Volume (km^3)	156.5	156.9	165	15.8
Approx. outflow : volume ratio	1:3	1:2	1:4	4: 1
Morphoedaphic Index (MEI)	2.8	9.2	6.1	6.6
Potential fish yield from MEI (kg/ha/year)	23.2	40.4*	32.77	34.6

Ref. Marshall (1984), Braimah (1995) * Actual 1978-1996 for Lake Nasser: 63-117 kg/ha/year based on catch statistics.

Table 188 **Hydrology and physico-chemical characteristics of the four African Lakes.**

Characteristics		L. Kariba	L.Nasser/Nubia	L. Kainji	L. Volta
Hydrology	River catchment	Zambezi	Nile	Niger	Volta (Black - White)
	Area catchment above dam (km^2)	823.200	2,400,000	1,600.000	394,000
	River flood season	Mar. Apr.	Aug. – Oct.	white flood (July - Sep.) Black flood (Dec. Feb.)	Jul.-Sep.
	Ann. Gross evaporation, (km^3)	4.2	24 (7.35 mm/day)	1.9 – 2.56	12.4
	Water level max. (m)	489	183	142	85.3
	Water level normal (m)	485	170-175	--	84.1
	Water level fluctuations (m)	3 – 4	7 – 10	9 – 10	3 – 4
	Water exchange ratio	1:4.0 (1:3.1)	1:2	4:1	1:3.7
	Temp. range, °C	17 – 32	15 – 36	23 – 31	25 – 34
Water Physics	Thermal cycle	Warm monomictic	Warm monomictic	(monomictic)	Warm polymictic
	Temp. homothermy (°C)	20 – 22 (June – July)	18.0	23 – 27.5	28.5 – (Jan – Mar) (July – Oct.)
	Thermal strat. period	Oct. - June	May – Aug.	Feb. mid May	Apr. June and Nov. – Dec.
	Depth of mixed layer, (m)	15 – 25	13 – 20	15 – 20	25 – 35
	Secchi D.V., (cm)	50 – 1060 (405)	5 – 740	10 – 300	10 – 450
	Depth euphotic zone, (m)	2 – 24 (10–16)	1 – 10	ab. 1 – 8	ab. 10
Water Chemistry	pH	6.8 – 8.9	6.8 – 9.6	6 – 8	6.8 – 8.5
	Conductivity (µmhos/cm)	50 – 115 (72)	186 – 299	40 – 54	50 – 80
	Total solids (mg/l)	40 – 70	69-200	(35 – 40)	60 – 80
	Diss. oxygen surf. (mg/l)	6 – 10	3.7 – 9.9	--	5 – 8
	Oxygen stratification	Oct. - June	May – Aug.	Mar. – mid May Oct. – Nov.	Nov. Jan. & Apr. – July

Lake is generally warm, monomictic with a single circulation period during winter. Thus, it has thermal stratification from May to August and more uniform temperature distribution between March and November (Entz 1976). Contrary to Lake Nasser, Lake Volta is warm polymictic, as the stratification is fairly stable in April - June, but frequently broken down during the rest of the year by southerly and harmattan winds and the annual floods (Braimah 1995).

Water level. Lake Volta reached its maximum level of 85.3 m in 1968 after the closure of the Dam in 1964. Seasonal variations were relatively moderate until 1975, when the water level started to drop, until June 1984, when the Lake reached an unprecedentedly low level of 71.9 m. At this level the Lake had shrunk to roughly half of its maximum size. Since then, Lake level fluctuated, but has been generally rising. The Lake reached its maximum level again in 1989, and again in 1991 (Braimah 1995).

In Lake Nasser water level reaches its maximum in November and December of each year, then it decreases gradually till the second half of July. The annual minimum level dropped from a maximum of 173.03 m in 1979 to a least minimum of 150.62m in 1988, after which it increased to an average of 175.66 m in 1999. The maximum operation level of 175 m above MSL was reached in October 1975, but recently, in 1999 water level reached a maximum of 181.6 m above sea level, which is considered as the highest record since the construction of AHD. Thus, the Lake's expected maximum level of 183 m, has not yet been reached.

In Lake Kainji, water level increases from August until it reaches to about 140 m in February, then decreases from March to July each year (Balogun & Ibeun 1995). Apart from the regular inflow of water from the River Niger, the reservoir experiences two major floods, namely the "white" flood and the "black" flood. The white flood, characterized by high turbidity, is a result of rainfall in the catchment area of the River Niger up to Mali, and it enters the Lake in late August. The black flood is caused by rainfall at the source of the Rive Niger, in Guinea, and enters the Lake in November and is characterized by a high water transparency.

Electrical conductivity. Electrical conductivity in Lake Nasser exhibits seasonal, vertical, horizontal and local variations ranging from 160 to 350 µmhos/cm, but the highest values were recorded just in front of the flood water (280-350 µmhos/cm) and the lowest at the end of the flood (160-200 µmhos/cm). Generally, conductivity values show a decreasing trend southwards in the different seasons, except for the summer, when a reverse picture is generally seen (Latif 1984a). Comparing electrical conductivity of Lake Nasser with that of Lake Volta (Table 188), the latter has very low values, ranging between 50.0 and 80.0 µmhos/cm. This may be due to the low values of total dissolved solids

which range between 30.60 and 37.92 mg/1 (Braimah 1995), contrary to Lake Nasser that has TDS 4-5 times higher than the other lakes.

pH. Generally, the pH values of Lake Nasser always lie on the alkaline side. Thus, the pH values range between 6.8 and 9.5 and decreases in general with depth. The lowest values were recorded in deep anoxic layers of the Lake. In Volta Lake, Obeng-Asamoah (1984) found also that the pH value of the surface water was about 7.0, declining with depth to 6.45 in the anoxic water near the bottom of the lake.

In Lake Nasser, bicarbonate **alkalinity** is common in most of its water and ranges from 58 to 146 mg/1 in the main channel of the Lake. Carbonate (0-32 mg/1) shows a decreasing pattern from year to year and in recent years has not constituted more than 1% of the total alkalinity (Aly 1992). In Lake Volta total alkalinity increased during the filling and post impoundment phases (Biswas 1966) and a total alkalinity of 41 mg $CaCO_3$/1 was recorded in 1989 (Braimah 1995). On the other hand, Lake Kariba is a slightly alkaline, oligotrophic lake, and this may be due to its relatively low photosynthesis rate and phytoplankton population (Machena 1995). Generally, the total alkalinity in Lake Nasser is 3-4 times higher than in the other three African lakes.

Nutrient salts. In Lake Nasser the total nutrient salts, PO_4, and NO_3 concentrations range between 0.07-0.52, and 0.5 – 3.0 mg/1 respectively, being generally higher in the bottom than in the surface layers. Lowest concentrations were recorded in February, while the highest ones were observed in November (Zaghloul 1985). Comparing Lake Nasser with Lake Volta, the latter has generally very low nutrient content and only traces of phosphate, nitrate, nitrite, ammonia and sulphate have been recorded in the upper 40 m of the Lake, while measurable quantities of these ions were recorded in the bottom waters (Braimah 1995). The low nutrient content was attributed to the catchment area itself being poor in nutrients, and also due to the low solubility of the Precambrian rock granites found in the upper catchment area (Antwi 1990). In Lake Kariba, both nitrogen and phosphorus are limiting (Marshall 1984). The latter author attributed this to the largely steeply sloping of the Lake, which limits the abundance and distribution of submerged macrophytes that affects the nutrient cycles and consequently the fish production.

PHYTOPLANKTON

Phytoplankton community in Lake Nasser is rich, both in species diversity and density. 107 species belonging to four divisions have been recorded. Numerically, the standing crop increases southwards (Mohammed *et al.* 1989) from 3.40 x 10^6 to 15.27 x 10^6 algal unit/l at Adindan. In surface water, the average density of phytoplankton is 6.3 x 10^6 algal unit/l, while it is only 2.08 x 10^6 at 20 m depth. Diatoms, green alage and blue-green algae are the dominant groups which exhibit seasonal fluctuation, strongly affected by the flood (Latif 1984a). Flood waters push great amounts of phytoplankton to the

northern region of the Lake. So, at the southernmost area (Adindan) the lowest densities are recorded during flood and post-flood seasons.

When comparing Lake Nasser with Lake Volta, the phytoplankton of the latter lake is quantitatively poor, especially in the southern region, and algal blooms are only observed occasionally in some limited areas (Obeng - Asamoah 1984). The number of the species is just over twenty and confined to not more than 10 genera. The most abundant species are *Synedra* and *Melosira* for the main channel, while *Oscillatoria* dominates the shallow arms and inshore areas. *Eudorina* and *Volvox* also occurred in relatively large numbers (Braimah 1995).

MACROPHYTES

Macrophyte communities play an important role in providing habitat complexity, food to aquatic animals, in nutrient recycling, etc. In Lake Nasser, eleven species were recorded since its filling, including 4 cosmopolitan species : *Potamogeton crispus, P. pectinatus , Najas marina* sub sp. *armata,* and *Zannichellia palustris,* as well as 4 subcosmopolitan species: *Potamogeton trichoides, P. lucens, Vallisneria spiralis* and *Najas horrida.* Subsequent to the construction of the Aswan High Dam, two euhydrophyte species seem to have disappeared from the region, *Alisma gramineum* and *Damasonium alisma. Najas marina* dominates the deep water zones at most sites and to a lesser extent in shallow waters, while *Vallisneria spiralis* dominates the submerged macrophytes, especially at Amada. In recent years *Myriophyllum spicatum* appeared in the Lake. It is worth mentioning that *Eichhornia crassipes* and *Pistia stratiotes* - which are found in some sections of the Nile River both upstream and downstream - have not been recorded in Lake Nasser and it is highly recommended to prevent infestation of the Lake with these pests.

On the other hand, the emergent aquatic macrophytes in Lake Kainji include *Echinochloa* spp., *Cyperus* sp., *Pistia stratiotes* and *Ceratophyllum demersum,* of which *Echinochloa stagnina* forms the major component (Balogun & Ibeun 1995). In 1971 emergent macrophytes were estimated to cover only 0.5% of the Lake surface area, but by 1977, 8.9% of the surface area was covered, in particular by *E. stagnina* (Obot 1984). The macrophytes in Lake Kainji are most productive in the dry season, when the Lake water level is highest, and are used as livestock fodder during the dry season.

In Lake Kariba the various types of shores have been colonized by macrophytes of different species and different growth forms. Exposed and rocky shores are not colonized by plants. *Vallisneria* sp. and *Potamogeton* sp. occupy shore areas with fine to sandy sediments. *Lagarosiphon* sp. occupies areas where sediments are rich in nutrients, with high light levels and low disturbance (Machena 1995).

Lagarosiphon sp. is fast growing, canopy forming and competes effectively. It forms more mixed groupings than the other species, and in fact mixed with all other species. *Vallisneria* forms the most monospecific group, while *Potamogeton* is mixed with neither *Ceratophyllum* nor *Najas.* There is evidence that *Lagarosiphon* sp. translocates phosphorus and ammonium from the sediments to littoral water (Machena 1989). Moreover, the mean net production rate of one individual of *Lagarosiphon* sp. shoots is about 7.5 mg/g (dw) / day (Machena 1995).

EPIPHYTES

Epiphytic algae are among the most important food items for the tilapiine species which constitute the major fish species of African Lakes. In Lake Nasser 28 predominant algal genera were recorded belonging to four major groups; Chlorophyta, Bacillariophyta, Cyanophyta and Pyrrophyta (Habib 1997). The predominant genera are *Oedogonium, Stigeoclonium* and *Spirogyra.* The maximum amount of chlorophyll *a* fluctuated from 10.9 in September to 78 mg/m^2 in November 1989. Generally low values of chlorophyll *a* were found in April or May. The calculated total amount of attached microalgae for the whole shoreline at 160 m water level was 421.4 ton in November 1989 (Habib, 1997), being the average value of Abu Simbel and Tushka areas.

In Lake Volta, the flooded trees provide a substrate for attached algae in the epilimnion of the inshore and offshore areas (Vanderpuye 1984). The most abundant species are *Synedra, Melosira* and *Oscillatoria* spp. In Lake Kariba, the dominant attached algae species are *Gleotrichi, Oscillatoria* and *Lyngbya* spp. The important substrata are the dead trees and macrophytes such as *Lagarosiphon* and *Najas* , while some species seem to be avoided (Ramberg *et al.* 1987). The attached algae have a mean biomass (dw) of 60 g/m^2 in the 0-5 m depth zone, where they are evenly distributed and contributed about 30% of macrophyte biomass (Ramberg *et al.* 1987).

PRIMARY PRODUCTIVITY

Primary productivity values of Lake Nasser show that it is eutrophic with highest production at 1-2 m depth. Samaan (1971) estimated primary production at different localities of the Lake and reported that it ranged between 2-3.5 g C/m^2 /day. Abdel-Monem (1995) recorded values ranging from 2.72-179.9 mg C/m^3/h. Gradual eutrophication of Lake Nasser may be a result of continuous sedimentation of organic matter which accumulates annually with flood water rich in nutrients that flourish phytoplankton growth. Comparing Lake Nasser with Lake Volta, the latter has very low values of primary productivity, ranging from 0.2-1.35 g C/m^3/day. This is primarily due to the limited supply of nutrients (Antwi 1990).

EVOLUTION AND HISTORICAL TRENDS OF DIFFERENT FISH GROUP CATCHES

A list of commercial fish species from the largest four African Lakes is presented in Table 189. It may be said that, in Lake Nasser there are 9 fish families and 23 species, in Lake Kainji - 11 families and 38 species, in Lake Kariba - 9 families and 22 species and in Lake Volta 12 families and 37 species (Table 189).

Table 189 **List of commercial fishes (Families and Species of the four African Lakes).**

Lake			
Nasser[1]	**Kainji[2]**	**Kariba[3]**	**Volta[4]**
Cichlidae	**Cichlidae**	**Cichlidae**	**Cichlidae**
Oreochromis niloticus	*Oreochromis niloticus*	*Oreochromis mortimeri*	*Sarotherodon galilaeus*
Sarotherodon galilaeus	*Sarotherodon galilaeus*	*Pharyngochromis darlingi*	*Oreochromis niloticus*
Centropomidae	*Tilapia zillii*	*Pseudocrenilabrus philander*	*Tilapia zillii*
Lates niloticus	*Hemichromis fasciatus*	*Serranochromis codrington*	*Chromidotilapia guentheri*
Bagridae	*Tilapia monodi*	*Tilapia rendalii*	*Leptotilapia irvinei*
Bagrus bajad	**Centropomidae**	**Cyprinidae**	*Hemichromis bimaculatus*
Bagrus docmak	*Lates niloticus*	*Labeo altivelis*	**Centropomidae**
Cyprinidae	**Bagridae**	**Clariidae**	*Lates niloticus*
Labeo niloticus	*Chrysichthys nigrodigitatus*	*Clarias gariepinus*	**Bagridae**
Labeo coubie	*Chrysichthys auratus*	*Heterobranchus longifilis*	*Bagrus docmak*
Labeo horie	*Clarotes laticeps*	**Characidae**	*Bagrus bajad*
Barbus bynni	*Bagrus bajad*	*Alests imberi*	*Chrysichthys nigrodigitatus*
Clariidae	*Bagrus docmak*	*Brycinus lateralis*	*Chrysichthys walkeri*
Clarias anguillaris	*Auchenoglanis biscutatus*	*Hydrocynus forskalii*	*Chrysichthys auratus*
Clarias gariepinus	*Auchenoglanis occidentalis*	*Micralestes acutidens*	*Auchenoglanis occidentalis*
Heterobranchus bidorsalis	**Cyprinidae**	**Mormyridae**	**Cyprinidae**
Heterobranchus longifilis	*Labeo senegalensis*	*Hippopotamyrus discorhynchus*	*Labeo coubie*
Characidae	*Labeo coubie*	*Marcusenius macrolepidotus*	*Raiamas senegalensis*
Hydrocynus forskalii	*Labeo parvus*	*Mormyrops deliciosus*	**Characidae**
Brycinus nurse	**Clariidae**	*Mormyrus longirostris*	*Brycinus nurse*
Alestes dentex	*Clarias anguillaris*	**Schilbeidae**	*Brycinus leuciscus*
Alestes baremoze	*Clarias gariepinus*	*Schilbe depressirostris*	*Brycinus macrolepidotus*
Mormyridae	**Characidae**	*Schilbe mystus*	*Hydrocynus forskalii*
Mormyrus kannume	*Alestes macrolepidotus*	**Mochokidae**	*Hydrocynus lineatus*
Mormyrus caschive	*Hydrocynus forskalii*	*Synodontis nebulosus*	**Mormyridae**
Shilbeidae	*Alestes dentex*	*Synodontis zambezensis*	*Mormyrus deliciosus*
Eutropius niloticus	*Alestes baremoze*	**Clupeidae**	*Mormyrus rume*
Schilbe mystus	*Alestes nurse*	*Limnothrissa miodon*	*Hippopotamus pictus*

Schilbe uranscopus	*Hydrocynus brevis*	**Malapteruridae**	*Pollimyrus isidori*
Mochokidae	**Mormyridae**	*Malapterurus electricus*	**Schilbeidae**
Synodontis spp.	*Mormyrus rume*		*Schilbe mystus*
	Hyperopsus bebe		*Silurandon auritus*
	Schilbeidae		**Mochokidae**
	Eutropius niloticus		*Synodontis gambiensis*
	Physallia pellucida		*Synodontis ocellifer*
	Mochokidae		*Synodontis schall*
	Synodontis gambiensis		*Synodontis eupterus*
	Synodontis schall		*Synodontis velifer*
	Synodontis nigrita		**Clupeidae**
	Synodontis filamentosus		*Pellonula afzeliusi*
	Synodontis gobrani		*Cynothrissa mento*
	Synodontis sorex		*Sierrathrissa leonensis*
	Distichodontidae		**Osteoglossidae**
	Distichodus rostratus		*Heterotis niloticus*
	Citharinus citharas		**Malapteruridae**
	Distichodus engycephalus		*Malapterurus electricus*
	Osteoglossidae		**Anabantidae**
	Heterotis niloticus		*Ctenopoma kingsleyae*
9 Families	**11 Families**	**9 Families**	**12 Families**
23 Species	**38 Species**	**22 Species**	**37 Species**

1: Latif (1974a and b and 1977), 2: Balogun (1986), 3: Machena (1995) 4: Braimah (1995).

COMPOSITION OF FISH LANDINGS AND CHANGES IN FISH POPULATIONS

Lake Nasser: Tilapiine species mainly *Sarotherodon galilaeus* and *Oreochromis niloticus* are the most dominant fish species, particularly during the period 1979-1999, as their percentage by weight were high and ranged between 83.12 and 95.29%, with an average of 88.48%. It is worth mentioning that, with the progressive increase of mean water level from 165.79 m MSL in 1991 to 178.92 m in 1999, there was a continuous decrease in tilapiine landings from 29,383 ton in 1991 to 8606 ton in 1999. This may be mainly attributed to that, a large portion of tilapiine catch is sold by the fishermen illegally in the black market with high prices, hence not recorded in the official catches and d'not represent the actual tilapiine catch from the Lake. Furthermore, it is probable that, with the increase of water level in the Lake, tilapiines are spread in very large areas, and hence are difficult to capture by the fishing gear in use.

The composition of fish landings in Lake Nasser is in favour of periphyton -plankton feeders. Thus, during the first period of inundation (1966-1972) the average percentage of the annual catch of periphyton- plankton feeders was only 39.92% (Table 106). This percentage increased gradually during the following periods, being 66.27 and 88.27% during the second (1973-1978) and third (1979-1996) periods (Table 106 and Fig. 150). On the other hand, the average percentage of the annual catch of carnivorous and zooplankton-insect feeders was 42.04% during the first period (1966-1972), which decreased gradually to 32.96 and 10.76%, during the second and third periods respectively. Furthermore, the average percentage of the annual catch of omnivorous fishes was 18.04% during the first period (1966-1972), followed by a sharp decrease to 0.77 and 0.97% during the second and third periods respectively (Table 106) and Fig. (150).

Lake Kainji : The pre-and post-impoundment fish species composition was described by Ita (1984). Two gill net surveys were carried out in 1976 (Ita 1984, Balogun 1986). Comparison of these two surveys reveals changes in species composition. In 1976, 58 species were recorded, while only 43 species were caught in 1984. The major difference between the catches in 1976 and 1984 was that, the Cichlidae, ranking third in terms of abundance in 1976, dominated the catches in 1984. The Bagridae and Cyprinidae, which formed low catches in the gill nets during the early post impoundment period (Lelek & El-Zarka 1973, Lewis, 1974) and ranked sixth and fourth respectively in 1976, became more important in 1984, ranking second and fourth respectively.

Major changes in species composition and the relative importance of the fish species and families were observed after impoundment of Lake Kainji. The Mormyridae and Distichodontidae were abundant in the River Niger, but after

impoundment, the Distichodontidae dominated the catches in the first two years and thereafter decreased in number. The Mormyridae did not feature well after the impoundment and remained very low, whereas the Cichlidae, Cyprinidae and Bagridae, which formed low catches in the River Niger and shortly after the impoundment, have significantly increased in number. The Characidae, which featured prominently in the River Niger, became dominant shortly after the impoundment and continued to remain prominent after the Lake became a tilapia lake in 1984.

A comparison of percentage composition by number of fish families in the regular gill net sampling in the period 1970 to 1973 and 1984 to 1985 is shown in Table 190.

Lake Kariba : Kenmuir (1984) analyzed experimental gill netting data collected by the Lake Kariba Fisheries Research Institute at two stations between 1960 and 1975, and Karenge (1992) analysed data collected at one of those stations between 1969 and 1991.

Table 190 *Comparison of percentage composition by number of fish families in the regular gill nets at Lake Kainji (Balogun & Ibeun 1995).*

Family	1970	1971	1972	1973	1984	1985
Characidae	44.5	37.2	19.9	11.9	13.4	11.1
Mochokidae	8.8	11.9	23.8	17.1	6.9	7.5
Cichlidae	1.0	1.0	1.0	2.9	28.9	8.7
Cyprinidae	5.0	3.5	3.5	2.1	12.9	7.4
Distichodontidae	9.9	10.5	10.5	6.3	1.4	16.3
Bagridae	8.7	14.7	14.7	17.4	20.4	19.9
Schilbeidae	16.9	19.3	19.3	35.6	10.7	19.6
Mormyridae	3.0	4.0	4.0	4.6	2.5	1.6
Centropomidae	1.6	2.5	2.5	1.1	2.8	5.2
Others	0	0.1	0.1	0.1	0.3	2.6
Number of fish	1283	22698	24698	13205	811	612
Number of fishing days	39	156	156	120	60	42
Average no. of fish caught/day	330	146.5	158.0	110.0	14	15

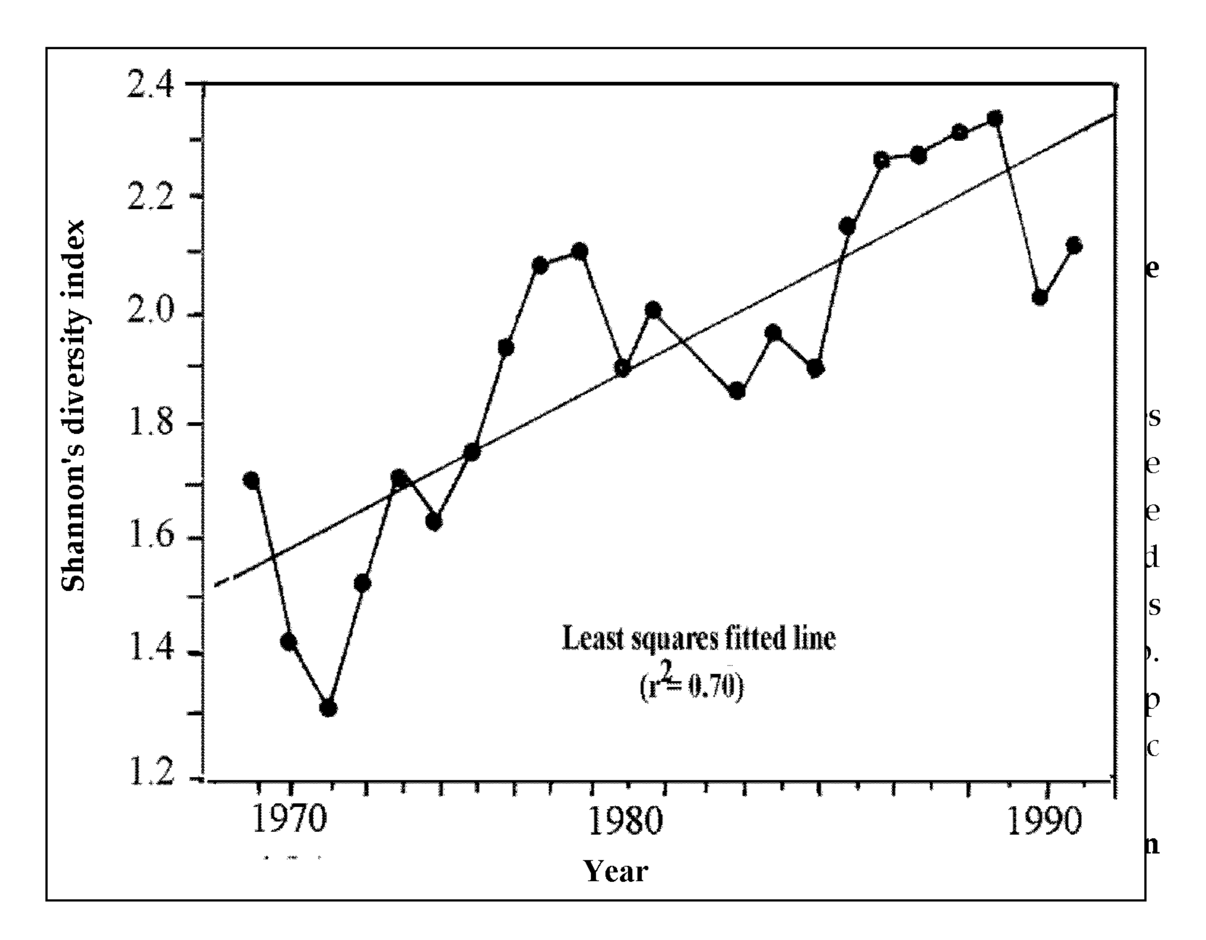
Note: Results for 1970-1973 were based on surface catches, while those, for 1984 -1985 were based on shore, surface and bottom catches.

After closure of the Dam in 1958 the fish population was similar to the pre-impoundment riverine population, with *Labeo* spp., *Distichodus* spp. *Clarias*

gariepinus and two characid species dominating gill net catches, while the fish biomass increased. In the early 1960's some of the early abundant species in the catch declined rapidly, e.g. *Clarias gariepinus, Labeo* spp. and *Distichodus* spp. At the same time, mormyrids (e.g. *Mormyrus longirostris),* cichlids (e.g., *Serranochromis codringtoni S. macrocephalus),* and silurids (e.g. *Synodontis zambezensis)* increased significantly in the catches. *Hydrocynus vittatus* increased significantly following the introduction and establishment of *Limnothrissa miodon*.

Using the Shannon Index, Karenge (1992) observed an increase in fish diversity at the Lakeside station between 1969 and 1991 (Fig. 260). Fish diversity and abundance followed increased abundance of macrophytes and benthic fauna, which was, for example, the case with *Serranochromis macrocephalus* (Karenge 1992).

Changes in fish population are still taking place (Sanyanga 1990). The catfish *Synodontis zambezensis* now seems to be the most abundant fish in the lake in terms of catch per unit effort. *Synodontis* is abundant in fished areas and occurs deeper than the other species. Increases in the population of benthic species is a common trend in the biological development of reservoirs. Studies have been undertaken to develop appropriate gear to commercially exploit this species (Songore 1992).



fresh weight equivalent (FWE) fish landings 1991 in Lake Volta (Braimah 1995).

Insect-aufwuchs, detritus feeders and herbivores		Piscivores		Semi-pelagic omnivores		Benthic - omnivores	
Species	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**
Heterotis niloticus	2.8	*Polypterus senegalus*		Clupeidae	0.5	Mormyridae	2.7
Distichodus spp.	0.5	*Gymnarchus niloticus*		Schilbeidae	1.7	*Auchanoglanis*	0.6
Citharinus spp.	4.7	*Hydrocynus* spp.	4.5	*Alestes* spp.	0.9	*Clarias* spp.	2.4
Labeo spp.	3.2	*Chrysichlhys* spp.	23.1	*Distichodus* sp.	0.5		
Synodontis spp.	15.8	*Bagrus* spp.	6.4				
Tilapia spp.	25.9	*Lates niloticus*	3.2				
		Tetraodon fahaka					
Total	52.9		37.8		3.6		5.7

Table 192 **Estimated fish yield of four African Lakes and their trophic states.**

	Lake			
	Nasser	**Kainji***	**Kariba****	**Volta*****
Estimated fish yield (kg/ha/yr)	55.58 -111.70 (av.73.70)	35.4 - 47.2	30 - 57	45.2
Trophic state	Eutrophic	Mesotrophic-eutrophic	Mesotrophic-eutrophic	Mesotrophic-eutrophic

* = Braimah (1995); **=Machena(1995); *** =Ita (1984).

ESTIMATED FISH YIELD

Table 192 presents the estimated fish yield of the four largest African Lakes. It is clear that the fish yield of Lake Nasser ranged between 55.58 and 111.70 kg/ha/yr, with an average of 73.70 kg/ha/yr during the period 1990-1996 (Table 192). This means that Lake Nasser may be categorized as an eutrophic Lake. On the other hand, the other three lakes (i.e. Kainji, Kariba and Volta) had fish yield less than 60 kg/ha/yr. Hence, Lakes Kainji, Kariba and Volta may be considered as mesotrophic - eutrophic (Table 192).

CONTENTS

		Page
PREFACE	by **Dr. N. M. Ebeid**, Minister of State for Environmental Affairs ..	
FOREWORD	by **Prof. M. A. Kassas**, Cairo University	1
INTRODUCTION		2
CHAPTER 1	GENERAL CHARACTERISTICS	7
	LOCATION	7
	MORPHOMETRY	7
	ABIOTIC	11
	BIOLOGICAL DIVERSITY	12
	GEOLOGY	13
	CLIMATE	16
	ORIGIN OF WATER	22
	HYDROLOGY AND SEASONAL FLOWS	25
CHAPTER 2	SEDIMENTATION	
	BEFORE CONSTRUCTION OF ASWAN HIGH DAM	29
	AFTER CONSTRUCTION OF ASWAN HIGH DAM	30
	Nature of sediments	34
	Effect of environmental factors on nature of sediments	35
	Heavy metal concentrations in relation to lake sediments ...	40
	CONCLUSIONS	43
CHAPTER 3	PHYSICAL ENVIRONMENT	45
	TEMPERATURE	46
	Surface water temperature and regional variations	46
	Thermal stratification.	47
	TRANSPARENCY	69
	WATER COLOUR	80
	CONCLUSIONS	81
CHAPTER 4	CHEMICAL ENVIRONMENT	82
	OXYGEN CONTENT	82
	ELECTRICAL CONDUCTIVITY	98
	HYDROGEN ION CONCENTRATION (pH)	103
	ALKALINITY	108
	MAJOR IONS	109
	NUTRIENTS	111
	CONCLUSIONS	115
CHAPTER 5	FLORA	118
	AQUATIC MACROPHYTES	118
	Euhydrophyte species	119
	Changes in the macrophyte flora of Egyptian Nubia over the time	123
	Effect of water level on aquatic macrophytes of Lake Nasser.	126
	ALGAE	129
	PHYTOPLANKTON	129
	Species diversity	129

Phytoplankton standing crop.......... 134
Horizontal, vertical and seasonal distribution. 138
WATER BLOOMS 145
CHLOROPHYLL *a*.......... 146
The main channel.......... 148
The Khors 155
Khor El-Ramla 155
Khor Kalabsha.......... 164
Chlorophyll a for net and nanoplankton.......... 165
Chlorophyll / phaeophytin ratio 168
PRIMARY PRODUCTIVITY 168
EPIPHYTES 171
FUNGI (MYCOFLORA) 172
BACTERIA 176
CONCLUSIONS 182

CHAPTER 6 ZOOPLANKTON AND ZOOBENTHOS 188
ZOOPLANKTON 188
The main channel.......... 188
Species diversity.......... 188
Density 189
Biomass 204
The Khors. 204
Species diversity.......... 204
Distribution. 205
ZOOBENTHOS. 207
Species diversity 207
Community composition 216
Successional changes of zoobenthos 217
CONCLUSIONS.......... 226

CHAPTER 7 FISH SPECIES DIVERSITY AND FISH BIOLOGY 229
FISH SPECIES DIVERSITY.......... 229
BIOLOGY OF IMPORTANT FISH SPECIES 233
FOOD AND FEEDING 233
AGE AND GROWTH 242
Length-weight relationship. 242
Effect of impoundment on the growth of *Tilapia* spp. in Lake Nasser 255
REPRODUCTIVE BIOLOGY 260
CONCLUSIONS.......... 275

CHAPTER 8 FISH PARASITES AND DISEASES.......... 278
PREVALENCE OF PARASITE INFECTION 278
SINGLE (PURE) INFECTION WITH ONE GENUS OF TREMATODES . 284
SIMULTANEOUS INFECTIONS WITH TWO GENERA OF TREMATODES 285
DISPERSION OF PARASITES WITH AGE OF HOST.......... 285
DISEASES FROM FISH PARASITES AND MEASURES FOR THEIR PREVENTION.......... 286

CONCLUSIONS 286

CHAPTER 9 FISHERIES 288
IMPORTANT FISHING SITES AND KHORS 288
FISH PRODUCTION 290
EFFECT OF DIFFERENT WATER LEVELS AND EFFORT ON FISH PRODUCTION 308
EFFECT OF CHANGEABLE SHORELINE LENGTH ON FISH PRODUCTION 317
Relation between total fish production and calculated length of shoreline ....
Lake Nasser 317
RELATIONSHIP BETWEEN CATCH AND GONAD INDEX 317
RELATIONSHIP BETWEEN PROHIBITING FISHING AND MATURITY 321
FISHING GEARS AND NETS 321
Mesh selectivity curves of trammel net 323
RELATIONSHIP BETWEEN EFFORT AND BIOMASS 327
VIRTUAL POPULATION ANALYSIS (VPA) AND TURNOVER RATIO 328
GEAR SELECTIVITY 328
POPULATION CHARACTERISTICS 333
DEMOGRAPHIC CHARACTERISTICS 338
CATCH PER UNIT EFFORT (CPUE) 341
Regional and seasonal fluctuations of total catch and CPUE.... 342
Relationship between CPUE of the total catch and of fish species catch and water level water level 363
Relationship between CPUE and effort 366
RECRUITMENT 370
Effect of water level on recruitment 370
Stock - recruitment relationship 372
COMPUTATION OF FISH YIELD 377
Prediction of potential annual yield using Morphoedaphic Index (MEI) 381
Predicting *Tilapia* spp. catch from water level and length of shoreline 383
Tentative estimation of fish production from phytoplankton primary production 389
ESTIMATION OF MAXIMUM SUSTAINABLE YIELD (MSY) 391
ESTIMATION OF FOOD QUANTITIES REQUIRED TO OBTAIN MAXIMUM SUSTAINABLE YIELD (MSY) 411
CONCLUSIONS. 414

CHAPTER 10 FISHERIES DEVELOPMENT 422
SOME NOTABLE FEATURES OF LAKE NASSER 422
FISH YIELD PREDICTIONS 423
THE YIELD PATTERN AT LAKE NASSER 424

FISHING INDUSTRY 426
FISHING REGULATIONS 426
FISHERIES POTENTIALS 427
RECOMMENDATIONS 428
CONCLUSIONS 431

CHAPTER 11 AQUACULTURE DEVELOPMENT 433
UTILIZATION OF COASTAL AREA 433
UTILIZATION OF OPEN WATER AREA 445
RESTOKING OF INDIGENOUS FISHES 452
CONCLUSIONS 458

CHAPTER 12 AMPHIBIAN, REPTILIAN AND AVIAN FAUNA 460
AMPHIBIAN FAUNA 460
REPTILIAN FAUNA 460
The Nile crocodile 460
The Nile monitor 471
The Nile turtle 471
AVIFAUNA 471
Impact of water birds on fisheries 474
CONCLUSIONS 479

CHAPTER 13 LAKE NASSER AND OTHER MAN-MADE AFRICAN RESERVOIRS 481
PHYSICO-CHEMICAL CHARACTERISTICS 481
PHYTOPLANKTON 486
MACROPHYTES 487
EPIPHYTES 488
PRIMARY PRODUCTIVITY 488
EVOLUTION AND HISTORICAL TRENDS OF DIFFERENT FISH GROUP CATCHES 489
COMPOSITION OF FISH LANDINGS AND CHANGES IN FISH POPULATIONS 490
ESTIMATED FISH YIELD 494

REFERENCES 495
INDEX 553
LAKE NASSER : FACTS & FIGURES
ARABIC TEXT
BIOGRAPHY OF AUTHORS

ACKNOWLEDGMENT

The authors would like to express their thanks and gratitude to ***Her*** Excellency ***Dr. Nadia Makram Ebeid,*** Minister of State for Environmental Affairs, for her interest and full support in the preparation of this book; and others of the Biodiversity series which will be an outstanding contribution to Biodiversity of Egypt.

We are particularly grateful to ***Dr. Mohammed A. Kassas,*** Professor of Botany and Applied Ecology, Cairo University for his interest, continuous encouragement and guidance. Without his inspiration and unyielding efforts, the present publication could not be completed.

The authors are grateful to ***Dr. Ibrahim Abdel Galil,*** Chief Officer of the Egyptian Environmental Affairs Agency (EEAA) who has given the present publication his full support, and to ***Prof.Dr.Essam El Badry,*** Director of the Nature Protection Department and Head of the National Biodiversity Unit (NBU) for his cooperation and help. The continuous efforts of ***Mr. Mohammed Ibrahim*** Deputy Director, Nature Protection Department is highly appreciated.

Our thanks are also due to ***Dr. Hassan Khashaba*** for his patience and skill in typing and arranging figures for final form.

PUBLICATIONS OF
NATIONAL BIODIVERSITY UNIT
EGYPTIAN ENVIRONMENTAL AFFAIRS AGENCY
(EEAA)

1- Habitat Diversity : Egypt 1993
2- Natural Protectorates in Egypt 1995
3- Egypt Country Study on Biological Diversity
(English & Arabic) 1995
4- Guide to Mammals of Natural Protectorates in Egypt
Prof. Dr. Kamal Wassif 1995
5- Egypt: National strategy and Action Plan for
Biodiversity Conservation 1998
6- Amphibians and Reptiles of Egypt
Prof. Dr. M. Saleh 1997
7- Biodiversity of Fungal Biota in Egypt, up-dated Checklist
(Including distribution, abundance and function)
Prof. Dr. S. El Abyad 1996
8- Birds known to Occur in Egypt
Prof. Dr. M.E. Tharwat 1997
9- Freshwater Fishes of Egypt
Prof. Dr. H.M. Bishai and Dr. M.T. Khalil 1997
10- Freshwater Molluscs of Egypt
Prof. Dr. A.M.Ibrahim, Prof. Dr. H.M.Bishai & Prof. Dr. M.T. Khalil 1999
11- Lake Nasser: A Treatise
Prof. Dr. H.M.Bishai, Prof. Dr. S.A. Abdel-Malek & Prof. Dr. M.T. Khalil .. 2000

ASSOCIATED PUBLICATIONS

1- Marine algae of Alexandria, Egypt
Prof. Dr. Anwar Abdel Aleem 1993
2- Flora of Egypt, Checklist
Prof. Dr. Loutfy Boulos 1995

FUTURE ISSUES

Fishes of the Egyptian coastal Mediterranean waters
Common Arachnids of Egypt
Mites of Egypt

NATIONAL BIODIVERSITY UNIT
23 A Ismail Mohammed St.
Zamalek, Cairo Egypt
Tel: 34067777
Fax: 0202/3405962
E-mail: EEAA4@idsc.gove.eg

First Published 2000

FOREWORD

The interest in molluscs dates back to the Ancient Egyptians who were fascinated with their colours and variability. Later, in recent times, scientists began to study **Freshwater Molluscs of Egypt** associated with the Nile and its canals, especially certain species of snails which play an important role in transmitting diseases to man and his livestock, causing great loss of the national income.

Complete eradication of pest snails is impossible for biological purposes. Nevertheless, thorough application of anti-snail measures at regular intervals can reduce the snail population, thus decreasing the incidence of infection. Any snail control campaign necessitates identification of snails, determination of their potentiality as vectors of diseases and the extent of their distribution.

Our knowledge of the various freshwater molluscs is rather scanty, especially for those species of no apparent medical importance. Many of the species have numerous subspecies or varieties. For research workers, it is difficult to find out a single reference or a manual key, and they have to consult many references before finding the correct identification. Even though, some of the questions on systematics of many species remain to be solved. Furthermore, knowledge of existing species will enable malacologists to register new species and the introduced ones.

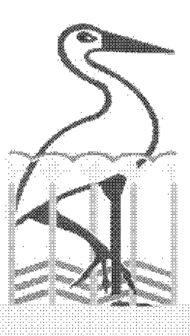
The authors of this particular welcome reference ***(Prof. A. Ibrahim, Prof. H. Bishai and Prof. M. Khalil)*** undertook the responsibility of revising and identifying the various freshwater molluscs occurring in Egypt either through thorough field collection for many years or records from the literature. In this reference book, they laid the basis of simple ways for identification of various species through simple keys. Their effort is considered the only consolidated study in the field of Freshwater Malacology so far in Egypt. Cordial thanks to the authors for their effort and valuable contribution.

Being one of the publications of the ***National Biodiversity Unit, Egyptian Environmental Affairs Agency,*** it is a most welcome addition to the series of which nine volumes are issued. This series is meant for sound identification of the various local species, their conservation and utilization.

Nadia Makram Ebeid

Minister of State for Environmental Affairs

ARAB REPUBLIC OF EGYPT
CABINET OF MINISTERS
EGYPTIAN ENVIRONMENTAL AFFAIRS AGENCY (EEAA)
DEPARTMENT OF NATURE PROTECTION

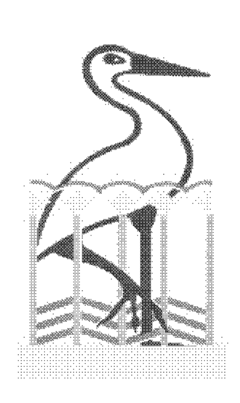


LAKE NASSER

Helmy M. Bishai
Samir A. Abdel-Malek
Magdy T. Khalil

Publication of National Biodiversity Unit. No. 11. 2000

ARAB REPUBLIC OF EGYPT
CABINET OF MINISTERS
EGYPTIAN ENVIRONMENTAL AFFAIRS AGENCY (EEAA)
DEPARTMENT OF NATURE PROTECTION



LAKE NASSER

A TREATISE

Helmy M. Bishai

Samir A. Abdel-Malek

Magdy T. Khalil

Publication of National Biodiversity Unit. No. 11. 2000